SPIE Corporate Member

R&D ULTRAFAST LASERS LTD.

Ultrarövid impulzusú lézerek és technológiák, valamint alkalmazásuk az élettudományokban

Szipőcs Róbert

R&D Ultrafast Lasers Kft.

E-mail: r.szipocs@szipocs.com

www.szipocs.com

„Szimpózium a hazai optikai kutatásokról és fejlesztésekről”, Siófok, 2015. június 8-9.
A szimpóziumot támogatta: TÁMOP-4.1.1.C-2012/1/KONV-2012-0005 projekt

SZÉCHENYI 2020
HUNGARIAN GOVERNMENT
European Union
European Social Fund
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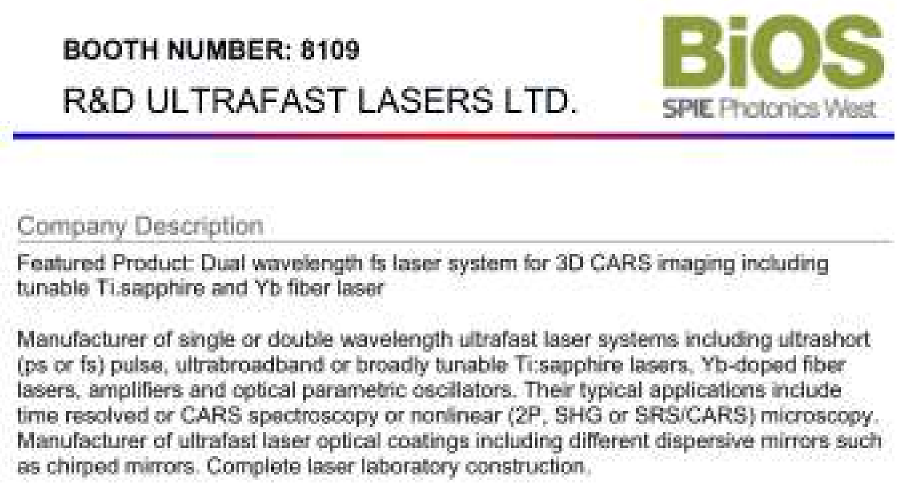
Bemutatkozás:
Az R&D Ultrafast Lasers Kutatási és Fejlesztési Kft.



BOOTH NUMBER: 8109

R&D ULTRAFAST LASERS LTD.

Company Description

Featured Product: Dual wavelength fs laser system for 3D CARS imaging including tunable Ti:sapphire and Yb fiber laser

Manufacturer of single or double wavelength ultrafast laser systems including ultrashort (ps or fs) pulse, ultrabroadband or broadly tunable Ti:sapphire lasers, Yb-doped fiber lasers, amplifiers and optical parametric oscillators. Their typical applications include time resolved or CARS spectroscopy or nonlinear (2P, SHG or SRS/CARS) microscopy. Manufacturer of ultrafast laser optical coatings including different dispersive mirrors such as chirped mirrors. Complete laser laboratory construction.

- Europhoton Conference, Neuchatel CH, August 2014
- On the Cover page of Experimental Dermatology, August 2014
- Mourou@70 Conference, Michigan USA, June 2014
- CARS imaging system installed at University of Szeged HU, June 2014
- IBRO 2014 Debrecen HU
- Innotrends 2013 Budapest HU
- Optics in the Life Sciences 2013 Hawaii USA
- Ultrafast Optics Conference 2013 Davos CH
- BIOS SPIE Photonics West 2013 San Francisco
  - R&D Presentation PDF file
  - R&D Presentation Video

We now offer a selection of articles co-authored by Dr. Szipőcs and his colleagues for download. The articles below are listed in reverse chronological order. You can access these documents by right-clicking on the titles.

(You will need Adobe Acrobat Reader to view these documents.)

Alapítva: 1997-ben

Telephely: 1121 Budapest, Konkoly Thege út 29-33. 6. ép. I. em. (KFKI Campus)

Infrastruktúra: 3 lézeroptikai laboratórium, 1 elektronikus és 1 gépészműhely, irodák, tárgyaló, raktár

Honlap: www.szipocs.com

Miről lesz szó?

1. Fotonika (lézerek + optika)
2. Orvosi diagnosztikai, gyógyszeripari alkalmazások (biológia)

Ezeket szokás együtt BIOFOTONIKÁ-nak is nevezni.

FemtoRose 100 TUN Compact/NoTouch (TM)
- hangolási tartomány 690–1050 nm
- szabadalmaztatott ultraszélessávú csörpölt tükör (UBCM) technológia
- beépített, mikroszkópból vezérelhető fényzár (shutter)
- számítógépről vagy mikroszkópból vezérelhető hullámhossz-beállítás
- teljesen automatizált, „hands free" működés
- Carl Zeiss mikroszkóp (ZEN szoftver) kompatibilitás
- beépített pumpa lézer
- teljesen zárt dobozolás, környezeti hatásoktól mentes működés

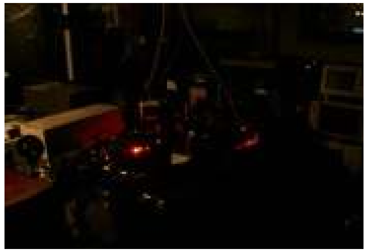
Az R&D Ultrafast Lasers Kft. – az Ön partnere a nemlineáris 3D mikroszkópiában

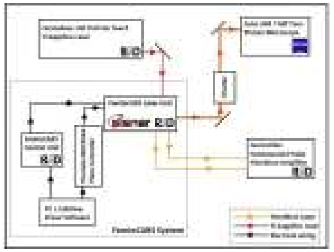
Egyéb kapcsolódó termékeink, szolgáltatásaink:
- ionosan porlasztott, kis diszperziójú vagy diszperziókompenzáló tükrök
- komplett lézerlaboratóriumok kiépítése
- szaktanácsadás, konzultáció
- femtoszekundumos lézerrendszerek szervizelése, karbantartása

Miről lesz szó?

1. Fotonika (lézerek + optika)

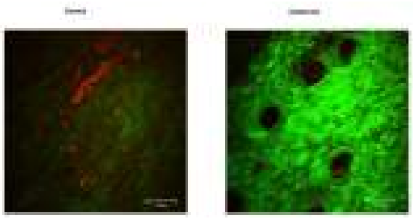
- ps-os, fs-os impulzusüzemű lézerek
- pásztázó nemlineáris mikroszkópia

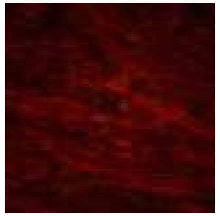


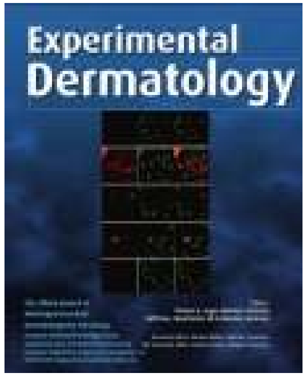


2. Orvosi diagnosztikai, gyógyszeripari alkalmazások (biológia)

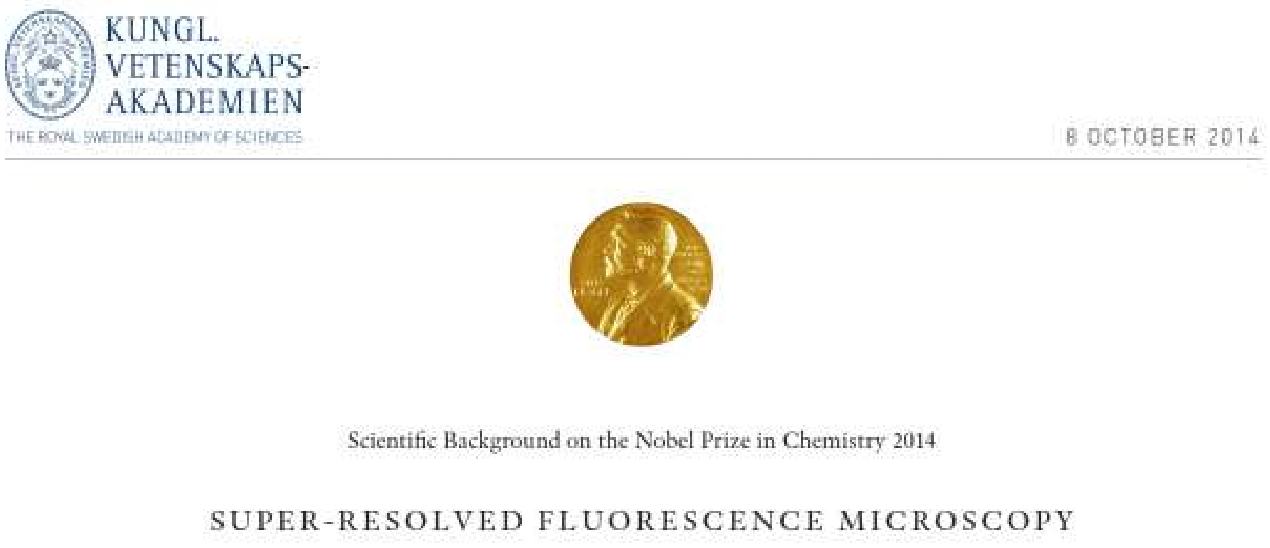
- bőrgyógyászat
- agykutatás
- gyógyszeripar







Miért fontos a Biofotonika, mióta foglalkozunk a szakterülettel?



KUNGL. VETENSKAPS-AKADEMIEN

THE ROYAL SWEDISH ACADEMY OF SCIENCES

8 OCTOBER 2014

Scientific Background on the Nobel Prize in Chemistry 2014

SUPER-RESOLVED FLUORESCENCE MICROSCOPY

Ld. még:

Szipőcs Róbert: Super-resolved fluorescence microscopy

(MTA Wigner RCP, Institute for Solid State Physics and Optics)

Abstract

Miért fontos a Biofotonika, mióta foglalkozunk a szakterülettel?

Hell developed the stimulated emission depletion (STED) microscopy method in 2000, which uses two laser beams—one stimulates fluorescent molecules to glow while another cancels out all fluorescence, except for that in a nanometer-sized volume. Scanning over the sample, nanometer for nanometer, yields an image with a resolution better than the diffraction limit.

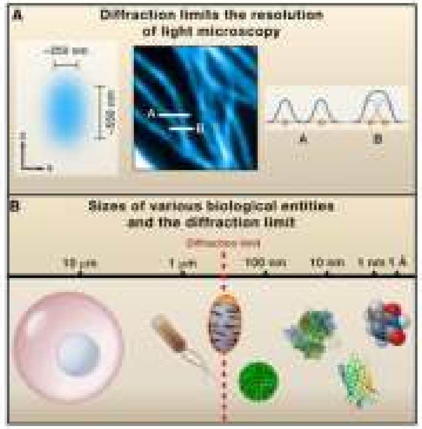
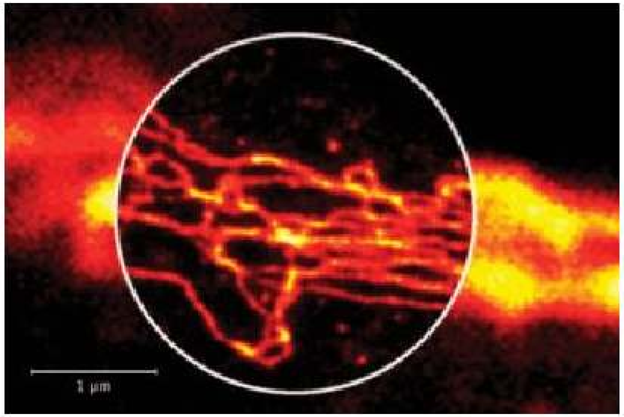
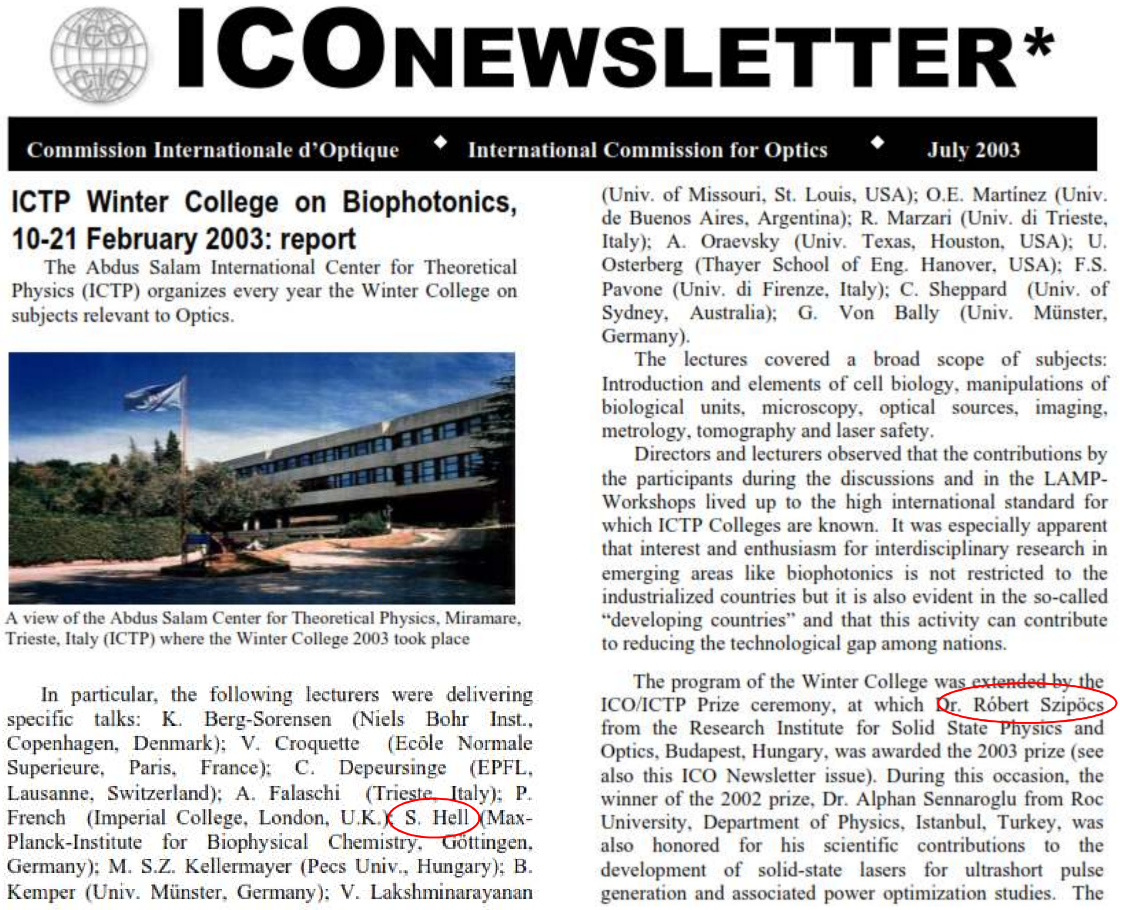


Figure 1: (Huang *et al.*, 2010, Cell, 143, 1047 – 57). **A**: (left) Focused laser beam, (middle) structure, (right) resolved (A) and not resolved (B) structural features. **B**: from left to right mammalian cell, *E. coli* cell, mitochondrion, influenza virus, ribosome, GFP, thymine.



The vimentin network of a neuron is revealed by confocal (outer) and nanoscale-resolution STED (inner part) modalities. The STED image shows single filaments that appear in the confocal reference as blurs. (*STED recording described in D.E. Wildanger et al., Opt. Exp., 16, 9614 –9621 [2008]; image courtesy of Stefan W. Hell*)

Miért fontos a Biofotonika, mióta foglalkozunk a szakterülettel?



ICONEWSLETTER*

Commission Internationale d'Optique ◆ International Commission for Optics ◆ July 2003

ICTP Winter College on Biophotonics, 10-21 February 2003: report

The Abdus Salam International Center for Theoretical Physics (ICTP) organizes every year the Winter College on subjects relevant to Optics.

A view of the Abdus Salam Center for Theoretical Physics, Miramare, Trieste, Italy (ICTP) where the Winter College 2003 took place

In particular, the following lecturers were delivering specific talks: K. Berg-Sorensen (Niels Bohr Inst., Copenhagen, Denmark); V. Croquette (Ecôle Normale Superieure, Paris, France); C. Depeursinge (EPFL, Lausanne, Switzerland); A. Falaschi (Trieste, Italy); P. French (Imperial College, London, U.K.); S. Hell (Max-Planck-Institute for Biophysical Chemistry, Göttingen, Germany); M. S.Z. Kellermayer (Pecs Univ., Hungary); B. Kemper (Univ. Münster, Germany); V. Lakshminarayanan (Univ. of Missouri, St. Louis, USA); O.E. Martínez (Univ. de Buenos Aires, Argentina); R. Marzari (Univ. di Trieste, Italy); A. Oraevsky (Univ. Texas, Houston, USA); U. Osterberg (Thayer School of Eng. Hanover, USA); F.S. Pavone (Univ. di Firenze, Italy); C. Sheppard (Univ. of Sydney, Australia); G. Von Bally (Univ. Münster, Germany).

The lectures covered a broad scope of subjects: Introduction and elements of cell biology, manipulations of biological units, microscopy, optical sources, imaging, metrology, tomography and laser safety.

Directors and lecturers observed that the contributions by the participants during the discussions and in the LAMP-Workshops lived up to the high international standard for which ICTP Colleges are known. It was especially apparent that interest and enthusiasm for interdisciplinary research in emerging areas like biophotonics is not restricted to the industrialized countries but it is also evident in the so-called "developing countries" and that this activity can contribute to reducing the technological gap among nations.

The program of the Winter College was extended by the ICO/ICTP Prize ceremony, at which Dr. Róbert Szipöcs from the Research Institute for Solid State Physics and Optics, Budapest, Hungary, was awarded the 2003 prize (see also this ICO Newsletter issue). During this occasion, the winner of the 2002 prize, Dr. Alphan Sennaroglu from Roc University, Department of Physics, Istanbul, Turkey, was also honored for his scientific contributions to the development of solid-state lasers for ultrashort pulse generation and associated power optimization studies. The

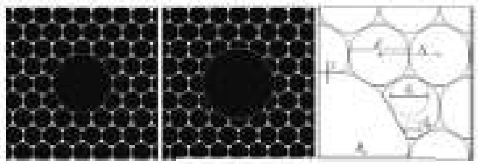
Femtoszekundumos lézerfizika, száloptika és nemlineáris mikroszkópia kutatócsoport

Szipőcs Group

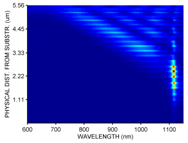
Tudományos háttér

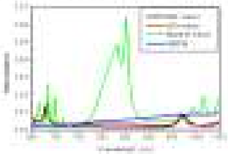
Fontosabb kutatási témák:

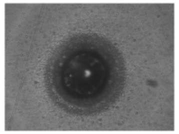
- *Fotonikus kristály optikai szálak elmélete, tervezése, gyártatása, minősítése és alkalmazásai optikai szállézerekben, erősítőkben és 3D mikroszkópiás orvosi diagnosztikai rendszerekben*
- ***Diszperzív lézeroptikai bevonatok roncsolódásának elméleti és kisérleti vizsgálata az 50 ps-nál hosszabb és a femtoszekundumos időtartományban***
- ***Femtoszekundumos szilárdtest- és száloptikai lézerek fejlesztése in vivo, nemlineáris 3D mikroszkópiás alkalmazásokhoz***
- ***Két hullámhosszon szinkron működő femtoszekundumos lézerrendszer CARS/SRS mikroszkópiához***
- ***Nemlineáris mikroszkópia alkalmazásai a bőrgyógyászat, az idegtudományok és a gyógyszeripar területén***
- ***Lézeres** biztonságtechnikai vizsgálatok*

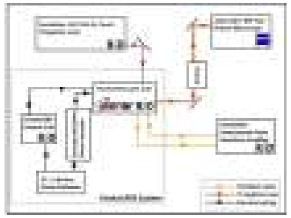


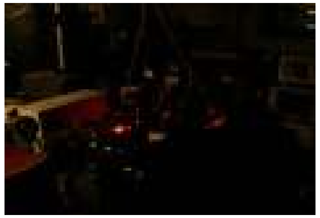
Üreges fotonikus kristály optikai szál – elméleti modell

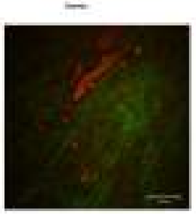


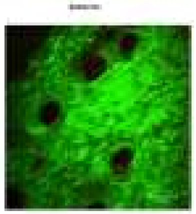


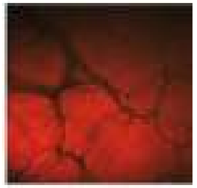








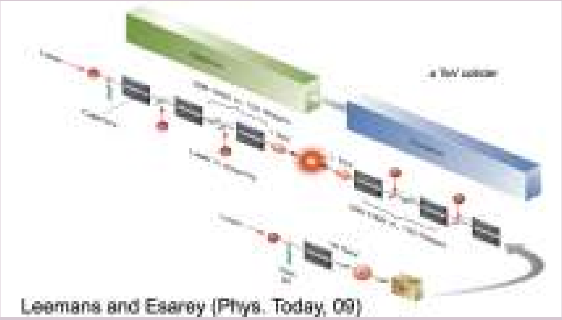




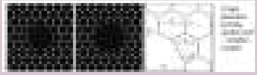
Az SZFI/ANO/femtoszekundumos lézer kutatócsoport
KOMPETENCIÁK

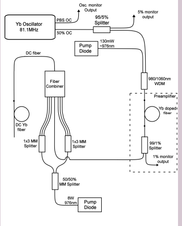
Szipőcs Group

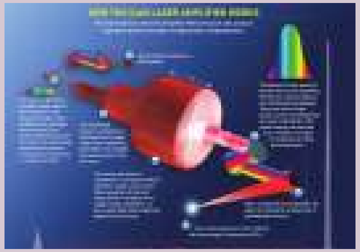
Részecskegyorsítás szállézerekkel (ICAN Projekt)



Leemans and Esarey (Phys. Today, 09)







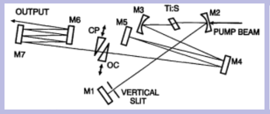

cost

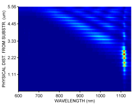
Southampton

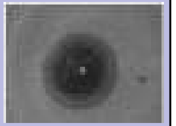
COST application: ICAN Bridge

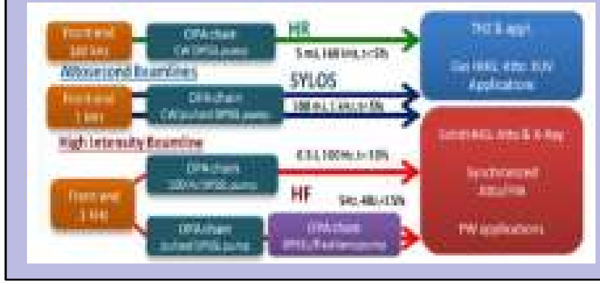
ican

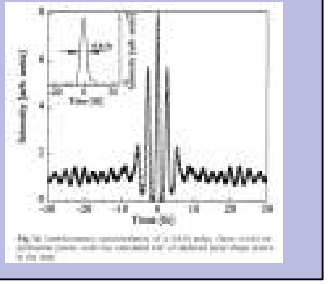
Femtoszekundumos szilárdtestlézerek és optika (ELI/Helios Projekt)



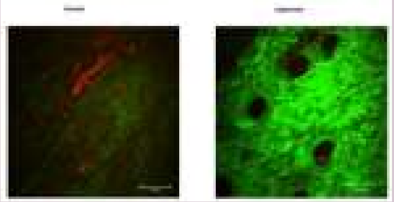


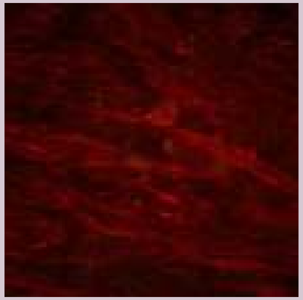






LifeScience@Wigner (pl. Nemzeti AgykutatásiProgram (NAP))





Femtoszekundumos lézerfizika, száloptika és nemlineáris mikroszkópia kutatócsoport

Szipőcs Group

Fontosabb tudományos közlemények (2008-2014)

1. Várallyay Z, Saitoh K, Fekete J, Kakihara K, Koshiba M, Szipőcs R: *Reversed dispersion slope photonic bandgap fibers for broadband dispersion control in femtosecond fiber lasers*, *OPTICS EXPRESS* 16, 15603-15616 (2008)

2. Fekete J, Várallyay Z, Szipőcs R: *Design of high bandwidth one- and two-dimensional photonic bandgap dielectric structures at grazing incidence of light*. APPLIED OPTICS 47, 5330-5336 (2008)

3. Fekete J, Cserteg A, Szipőcs R: *All-fiber, all-normal dispersion ytterbium ring oscillator, LASER PHYSICS LETTERS* 6, 49-53 (2009)

4. Várallyay Z, Saitoh K, Szabó Á, Szipőcs R: *Photonic bandgap fibers with resonant structures for tailoring the dispersion*, *OPTICS EXPRESS* 17, 11869-11883,(2009)

5. Antal P, Szipőcs R: *Tunable, low-repetition-rate, cost-efficient femtosecond Ti:sapphire laser for nonlinear microscopy*, *APPL. PHYS. B107*, 17–22 (2012)

6. Antal P, Szipőcs R: *Relation between group delay, energy storage and loss in dispersive dielectric mirrors*, *CHINESE OPTICS LETTERS* 10, 053101/1-4 (2012)

7. P. Bognár, D. Haluszka, N. Wikonkál, A. Kolonics, R. Szipőcs, S. Kárpáti, *Reduced Inflammatory Threshold Indicates Skin Barrier Defect in Transglutaminase 3 Knockout Mice, J. INVESTIGATIVE DERMATOLGY* 134, *105-111* (2014)

8. Grósz T, Kovács AP, Kiss M, Szipocs R, Measurement of higher order chromatic dispersion in a photonic bandgap fiber: Comparative study of spectral interferometric methods, *APPLIED OPTICS* 53, *1929-1937* (2014)

9. Kolonics A, Csiszovszki Zs, Tőke ER, Lőrincz O, Haluszka D, Szipőcs R, *In vivo study of targeted nanomedicine delivery into Langerhans cells by multiphoton laser scanning microscopy, EXPERIMENTAL DERMATOLOGY* 23, *596-605* (2014)

10. Toke ER, Lorincz O, Csiszovszki Z, Somogyi E, Felföldi G, Molnár L, Szipőcs R, Kolonics A, Malissen B, Lori F, Trocio J, Bakare N, Horkay F, Romani N, Tripp CH, Stoitzner P, Lisziewicz J, *Exploitation of Langerhans cells for in vivo DNA vaccine delivery into the lymph nodes*, *GENE THERAPY* 21, *566-574.*(2014)

11. Várallyay Z, Szipőcs R, *Stored Energy, Transmission Group Delay and Mode Field Distortion in Optical Fibers, IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS* 20, 0904206/1-6 (2014)

I. FEMTOSZEKUNDUMOS SZILÁRDTESTLÉZEREK ÉS OPO-K

I. Szub-10-fs-os Ti-zafír lézer (FemtoRose 10 MDC/PRC)
II. Hangolható 100 fs-os Ti-zafír lézer (FemtoRose 100 TUN NT)
III. Hosszúrezonátoros, hangolható Ti-zafír lézer (FemtoRose 300 TUN LC)
IV. Diódapumpált, tükörkompenzált Cr:LISAF és Nd:glass lézer (prototípusok)
V. Szinkronpumpált, PPLN optikai parametrikus oszcillátor (FemtoRainbow OPO)

II. FS-OS SZILÁRDTESTLÉZER TECHNOLÓGIÁK

I. Szélessávú erősítő közegek, szolitonszerű impulzusformálás (SPM + GDD < 0)
II. Szélessávú visszacsatolás és diszperziókompenzálás (prizmapár és csörpölt tükrök)
III. Módusszinkronizálás (Kerr-lencse, SESAM)
IV. Diódapumpálás, kisveszteségű diszperziókompenzáló tükrök (IBS)
V. Frekvenciakonverzió, PPLN, kvázi-fázisillesztés
VI. Rezonátor modellek
VII. Gépészeti tervezés, mechatronika (elektronikusan vezérelt eltolók, tükörállítók)
VIII. Vezérlő elektronikák, szoftverek

Femtoszekundumos lézerek működésének alapjai

1 fs = 10^{-15} s

1 fs * 300 000 km/s = 0.3 mikron

→ Az optikai vékonyréteg rendszerek kiemelkedő szerepe

Fourier-transzformációs kapcsolat az komplex térerősség időfüggvény és a komplex amplitudó spektrum között:

$\Delta\omega\ \Delta\tau \geq$ állandó

Femtoszekundumos lézerműködés alapvető feltételei:

☐ **Nagy sávszélességgel rendelkező erősítő közeg**

☐ **Módusszinkronizálás (pl. Kerr-lencsés)**

☐ **Diszperziókompenzálás (szolitonszerű impulzusformálódás)**

A Ti-zafír kristály, mint nagy sávszélességgel rendelkező erősítő közeg

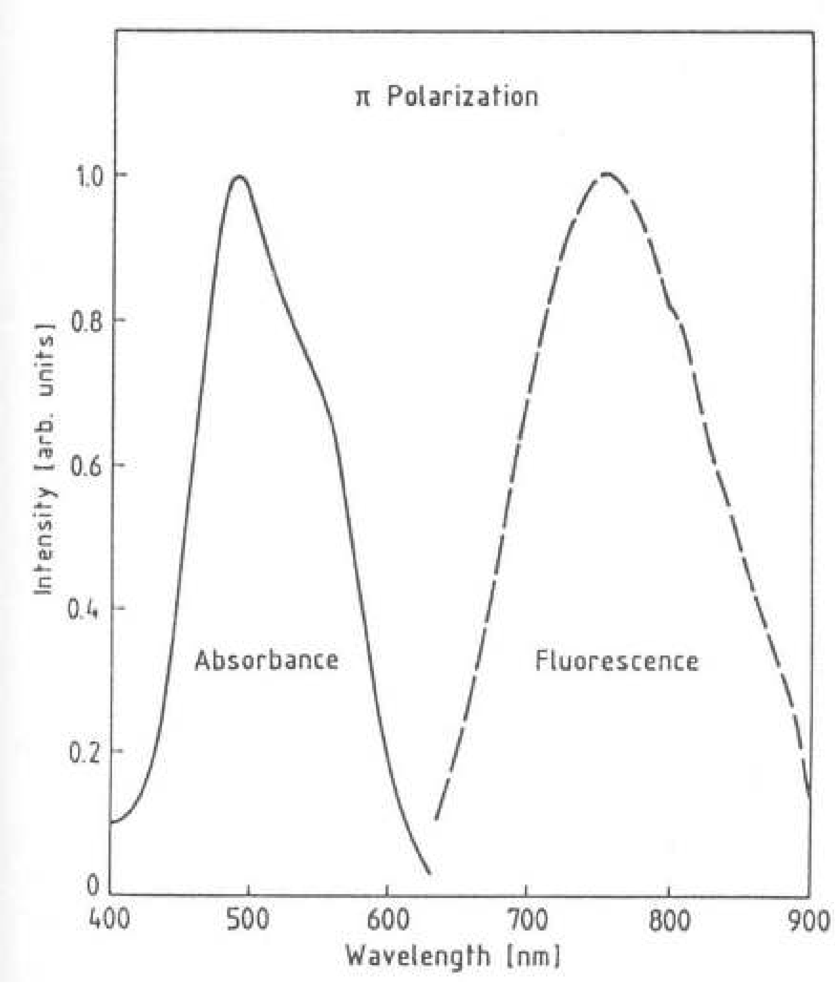


Fig. 2.24. Absorption and fluorescence spectra of the Ti^{3+} ion in Al_2O_3 (sapphire) [2.165]

Table 2.12. Laser parameters of $Ti:Al_2O_3$

Index of refraction	$n = 1.76$
Fluorescent lifetime	$\tau = 3.2\,\mu s$
Fluorescent linewidth (FWHM)	$\Delta\lambda \sim 180\,nm$
Peak emission wavelength	$\lambda_p \sim 790\,nm$
Peak stimulated emission cross section	
parallel to c axis	$\sigma_{p\parallel} \sim 4.1 \times 10^{-19}\,cm^2$
perpendicular to c axis	$\sigma_{p\perp} \sim 2.0 \times 10^{-19}\,cm^2$
Stimulated emission cross section at $0.795\,\mu m$ ($\parallel c$ axis)	$\sigma_{\parallel} = 2.8 \times 10^{-19}\,cm^2$
Quantum efficiency of converting a $0.53\,\mu m$ pump photon into an inverted site	$\eta_Q \approx 1$
Saturation fluence at $0.795\,\mu m$	$E_{sat} = 0.9\,J/cm^2$

A Cr:LISAF kristály, mint nagy sávszélességgel rendelkező erősítő közeg

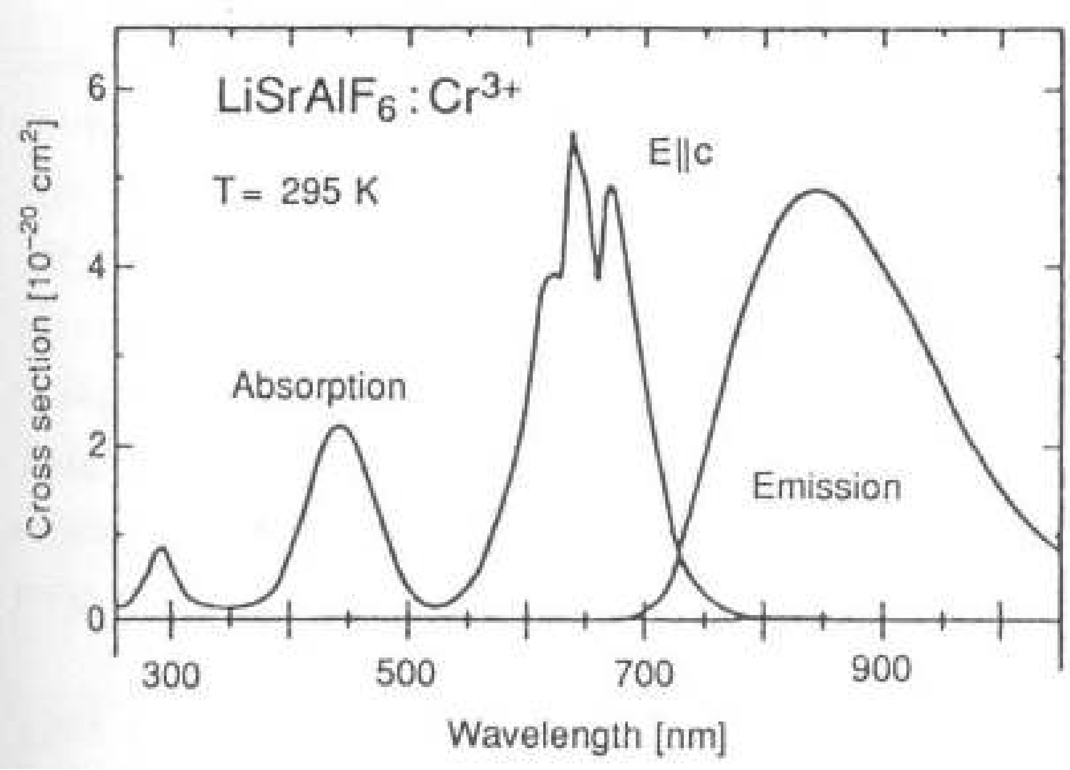


Fig. 2.26. Absorption and emission spectra of Cr : LiSAF

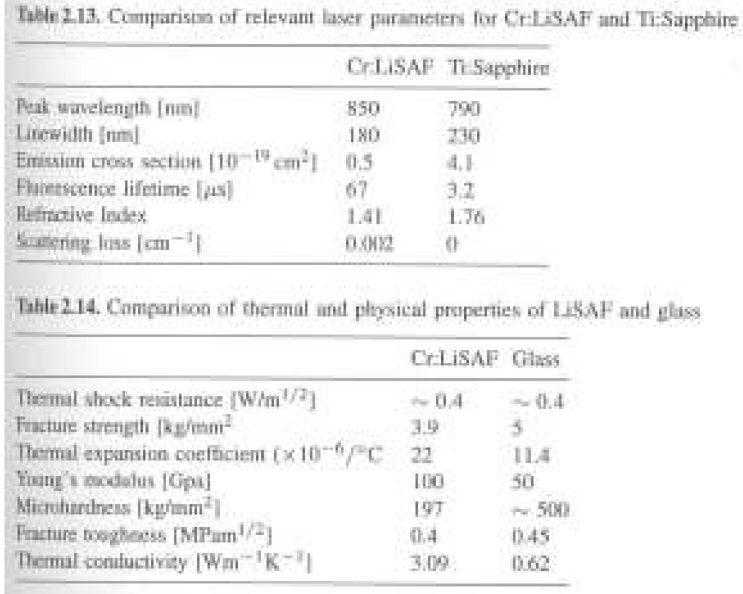


Table 2.13. Comparison of relevant laser parameters for Cr:LiSAF and Ti:Sapphire

	Cr:LiSAF	Ti:Sapphire
Peak wavelength [nm]	850	790
Linewidth [nm]	180	230
Emission cross section [10^{-19} cm^2]	0.5	4.1
Fluorescence lifetime [μs]	67	3.2
Refractive Index	1.41	1.76
Scattering loss [cm^{-1}]	0.002	0

Table 2.14. Comparison of thermal and physical properties of LiSAF and glass

	Cr:LiSAF	Glass
Thermal shock resistance [W/m$^{1/2}$]	~ 0.4	~ 0.4
Fracture strength [kg/mm^2	3.9	5
Thermal expansion coefficient ($\times 10^{-6}$/°C	22	11.4
Young's modulus [Gpa]	100	50
Microhardness [kg/mm^2]	197	~ 500
Fracture toughness [MPam$^{1/2}$]	0.4	0.45
Thermal conductivity [Wm^{-1}K^{-1}]	3.09	0.62

A módusszinkronizálás

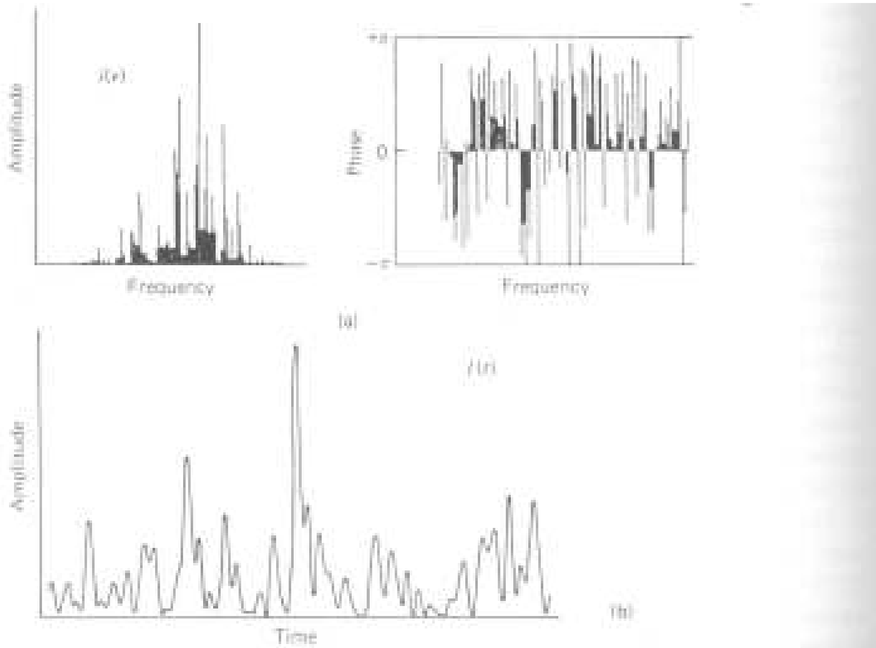


Fig. 9.1a,b. Signal of a non-mode-locked laser. In the frequency domain **(a)** the intensities $i(\nu)$ of the modes have a Rayleigh distribution about the Gaussian mean and the phases are randomly distributed. In the time domain **(b)** the intensity has the characteristic of thermal noise

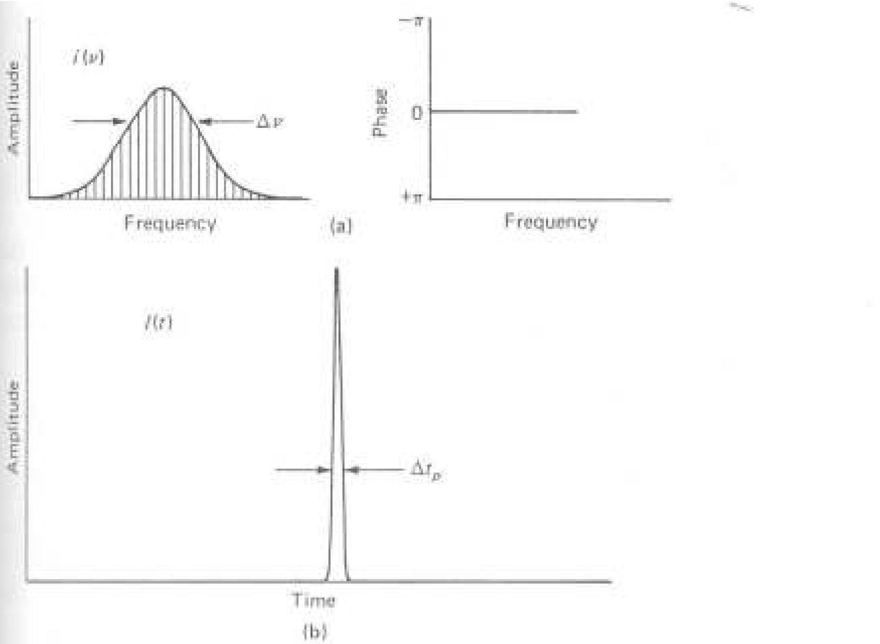
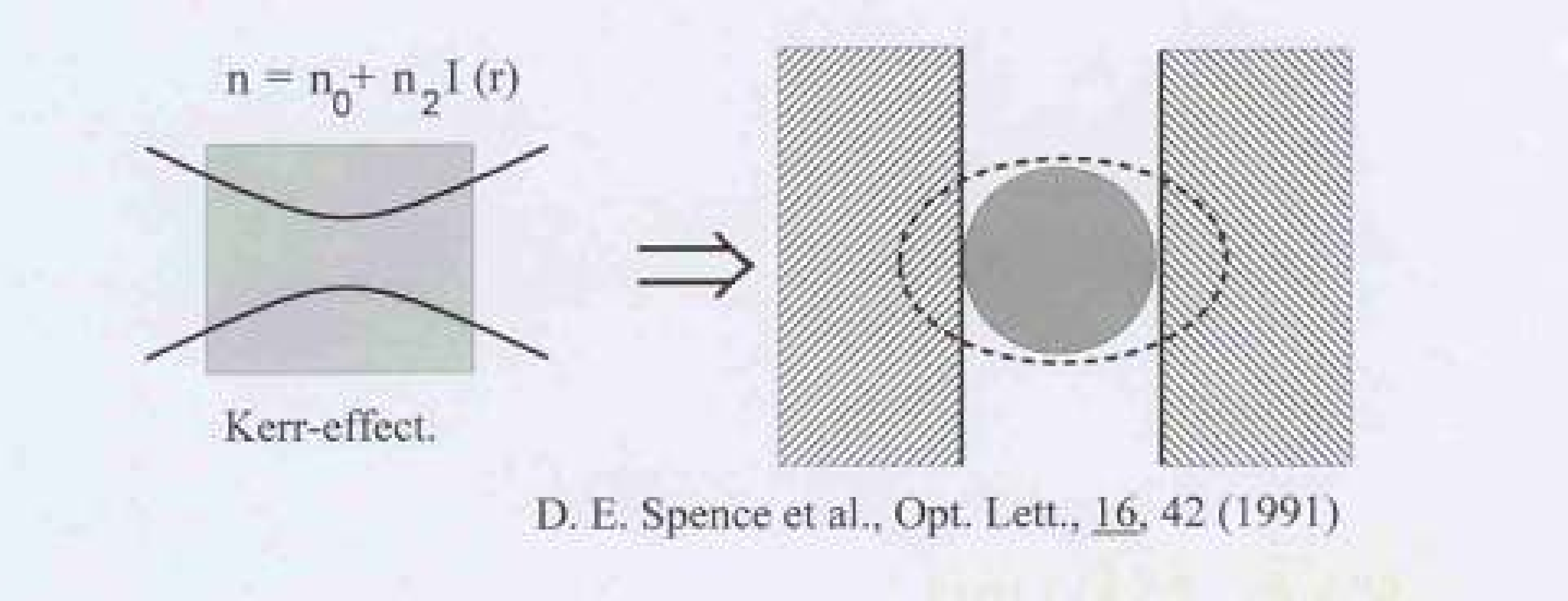


Fig. 9.2a,b. Signal structure of an ideally mode-locked laser. The spectral intensities **(a)** have a Gaussian distribution, while the spectral phases are identically zero. In the time domain **(b)** the signal is a transform-limited Gaussian pulse

Kerr-lencsés módusszinkronizálás



D. E. Spence et al., Opt. Lett., 16, 42 (1991)

A diszperzió hatása az impulzusokra

$$\phi(\omega) = \phi_0 + \phi'(\omega-\omega_0) + {}^1\!/_2\,\phi''(\omega-\omega_0)^2 + {}^1\!/_6\,\phi'''(\omega-\omega_0)^3 + \ldots \quad (1)$$

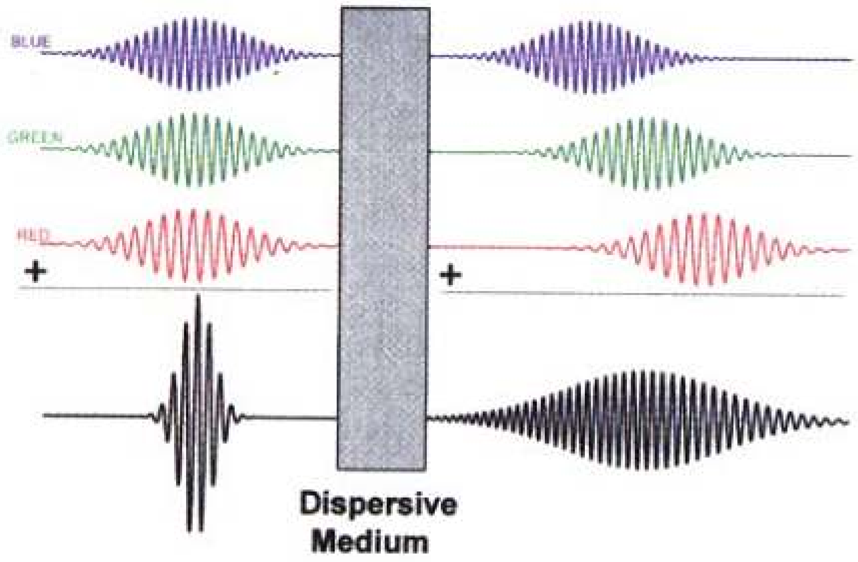
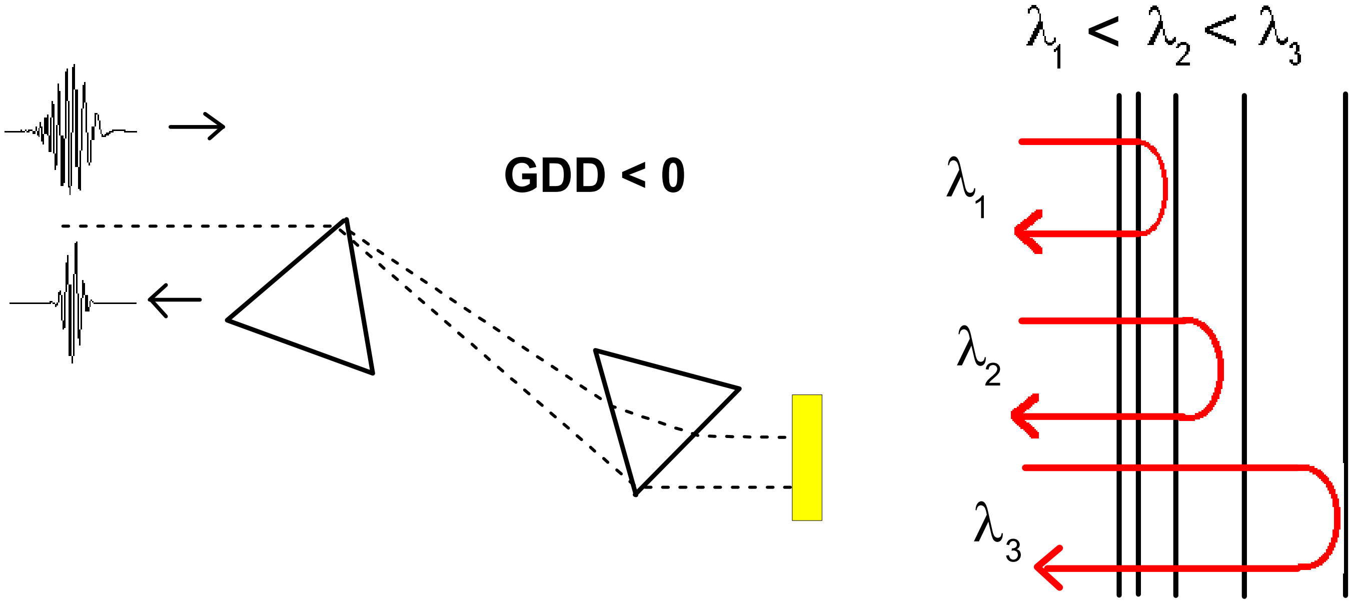


Figure 1. Optical pulse propagation through a dispersive medium: a frequency-dependent group delay leads to a pulse broadening and to a carrier frequency sweep.

Kisveszteségű diszperziókompenzálás prizmapárral és csörpölt tükrökkel



Zs. Bor, B. Rácz, Opt. Comm., 54, 165 (1985)

R. Szipőcs, K. Ferencz, Ch. Spielmann, F. Krausz, *Opt. Lett.* 19(3), 201-203 (1994)

R. Szipőcs, A. Kőházi-Kis, Appl. Phys. B65, 115 (1997)

R. Szipőcs, F. Krausz U. S. Pat. No.: 5, 734, 503

A femtoszekundumos lézerek teljesítőképességét korlátozó tényezők

- Az erősítő közeg véges sávszélessége
- Az alkalmazott kisdiszperziójú lézertükrök véges sávszélessége
- A magasabbrendű diszperzió hatása

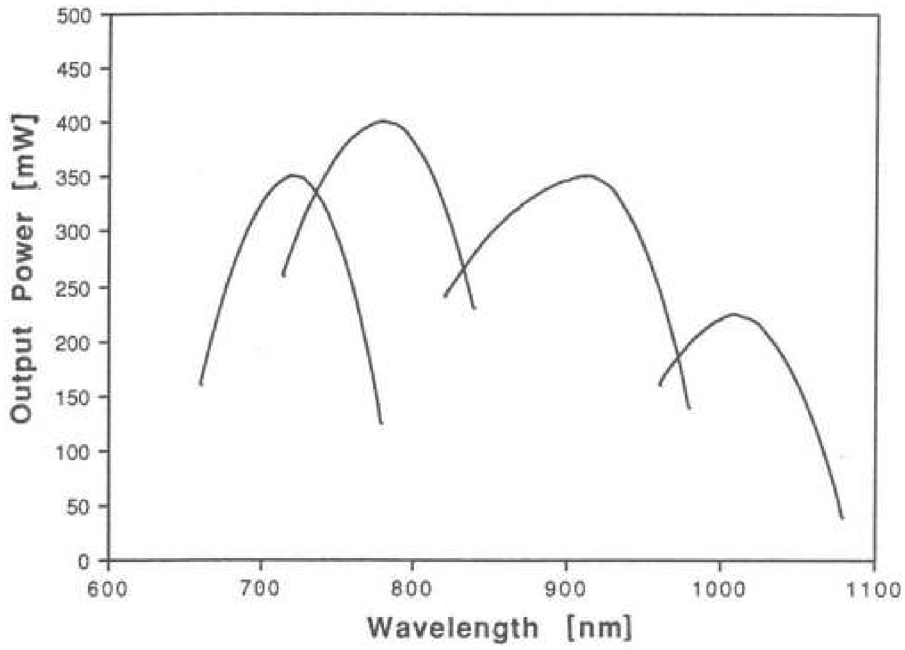


Fig. 2.25. Tuning range of a Ti:sapphire laser pumped by a Nd:YLF laser at 1 kHz [2.147]

A csörpölt tükrök előnyös tulajdonságai:

1. Közel állandó másodrendű illetve tervezhető harmadrendű diszperzió

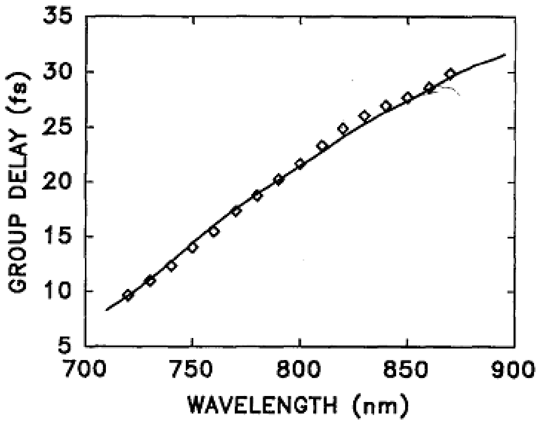


Fig. 3. Computed group delay as a function of wavelength (solid curve) together with experimental data (squares) for the multilayer design of Fig. 1. Note that the absolute delay could not be measured; therefore a wavelength-independent constant delay was added to the measured relative data.

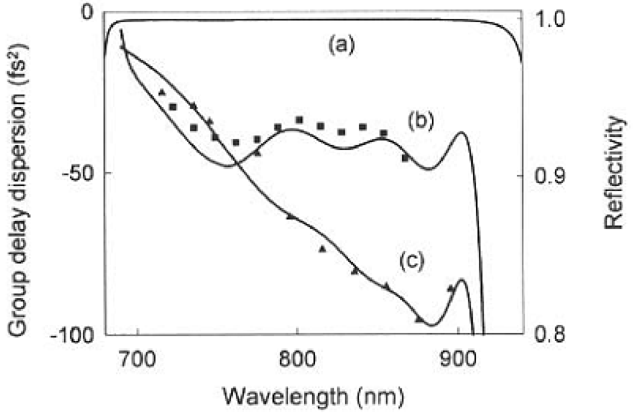


Figure 3. Curve (a): calculated reflectivity of chirped mirrors described in the text. The reflectivity is somewhat less (≈ 99.5%) in reality due to scattering losses not included in the calculations. Curves (b) and (c): calculated GDD of chirped mirrors designed for GDD and TOD compensation, respectively. The squares and triangles represent measured data points obtained with spectrally-resolved[15] and conventional[16] white-light interferometry, respectively.

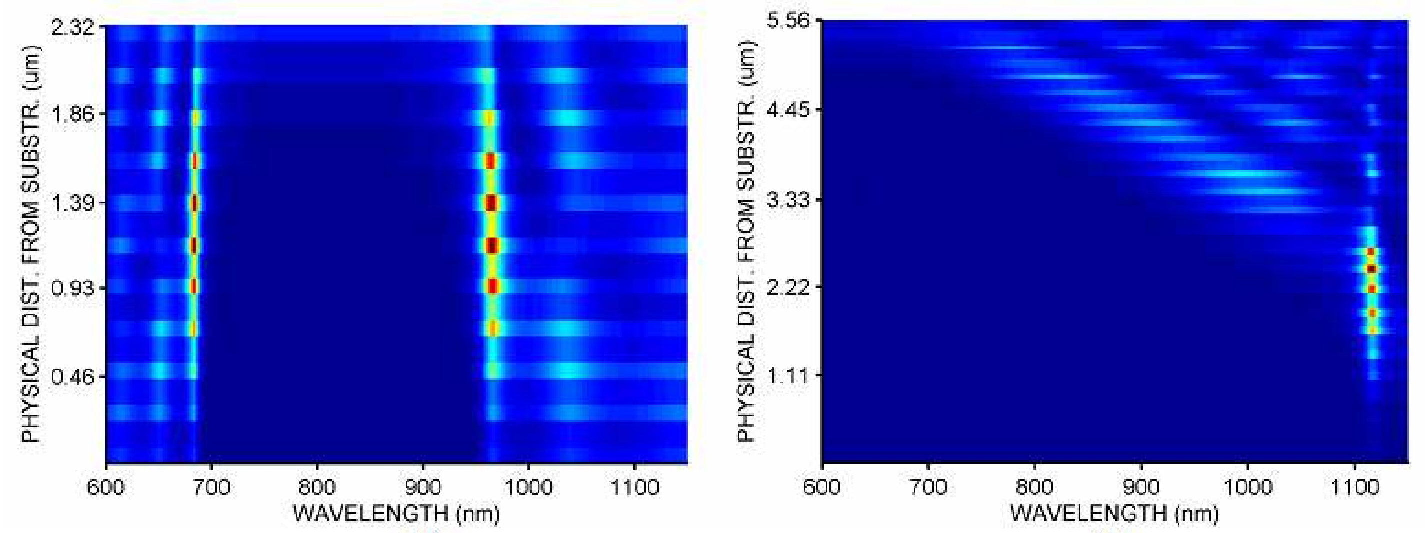
R. Szipőcs, K. Ferencz, Ch. Spielmann, F. Krausz, *Opt. Lett.* 19(3), 201-203 (1994)

R. Szipőcs, A. Kőházi-Kis, Appl. Phys. B65, 115 (1997)

R. Szipőcs, F. Krausz U. S. Pat. No.: 5, 734, 503

A csörpölt tükrök előnyös tulajdonságai:

2. A csörpölt tükrök megnövekedett spektrális sávszélessége



(a)

(b)

(a) Kisdiszperziójú negyedhullámú tükör (HR tartomány :~ 700-900 nm)

(b) Ultraszélessávú csörpölt dielektrikumtükör (HR tartomány: ~ 660-1060 nm)

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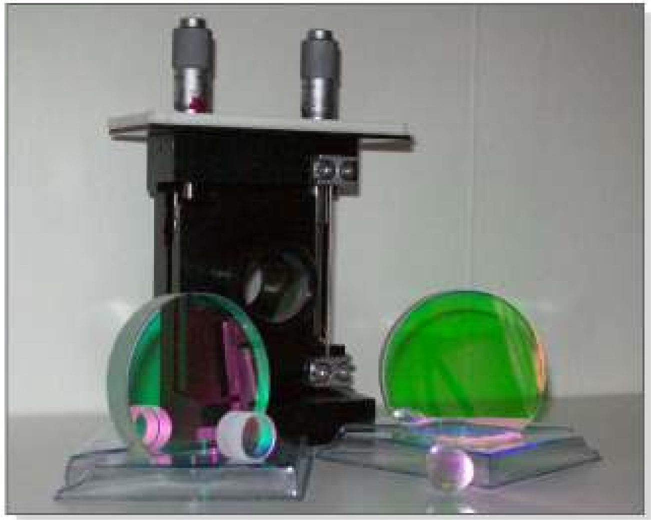
Patents

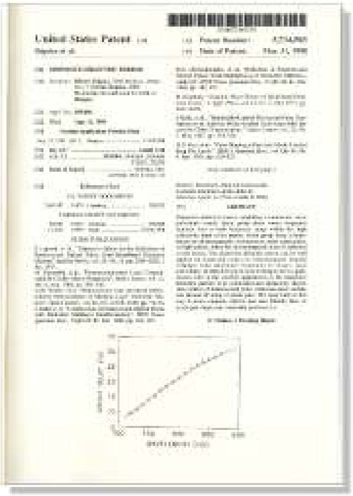


SZABADALMI OKIRAT

The United States of America

The Commissioner of Patents and Trademarks

United States Patent



United States Patent

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PAST: INVENTING CHIRPED MIRRORS IN 1993 (Wigner RCP / TU Wien)

THE SOLUTION FOR ULTRAFAST SOLID STATE LASERS

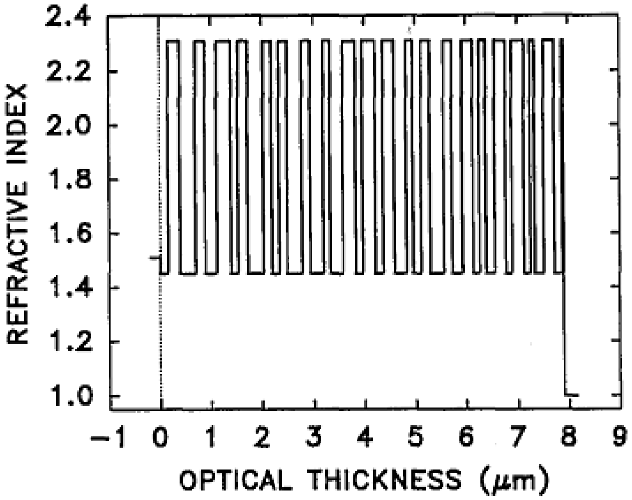


Fig. 1. Theoretical refractive-index profile of a high-reflectivity TiO_2–SiO_2 multilayer coating designed specifically for broadband GDD control in femtosecond lasers.

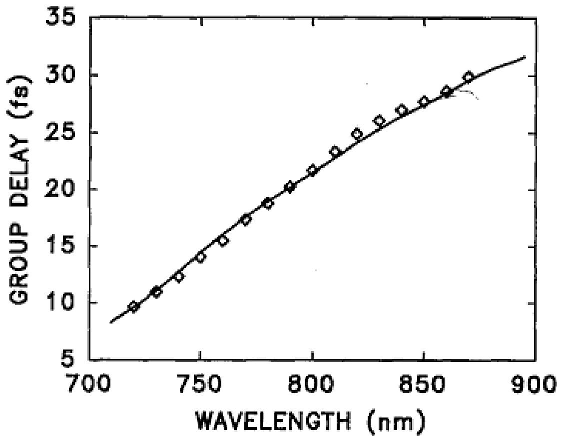


Fig. 3. Computed group delay as a function of wavelength (solid curve) together with experimental data (squares) for the multilayer design of Fig. 1. Note that the absolute delay could not be measured; therefore a wavelength-independent constant delay was added to the measured relative data.

R. Szipőcs, K. Ferencz, Ch. Spielmann, F. Krausz, *Opt. Lett.* 19, pp. 201-203 (1994)

R. Szipőcs, F. Krausz: Dispersive dielectric mirror; U. S. Pat. No.: 5,734,503 (1993)

DISPERSIVE MIRRORS, CHARACTERIZATION: WHITE LIGHT INTERFEROMETRY

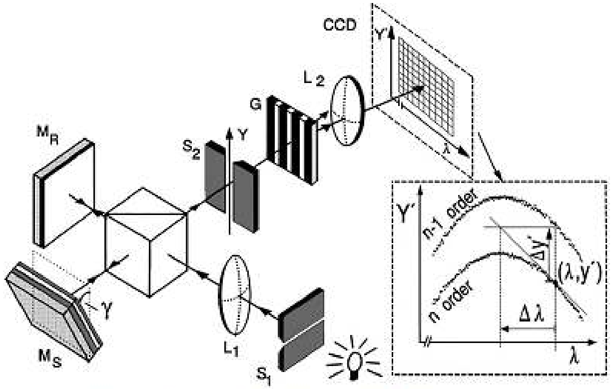
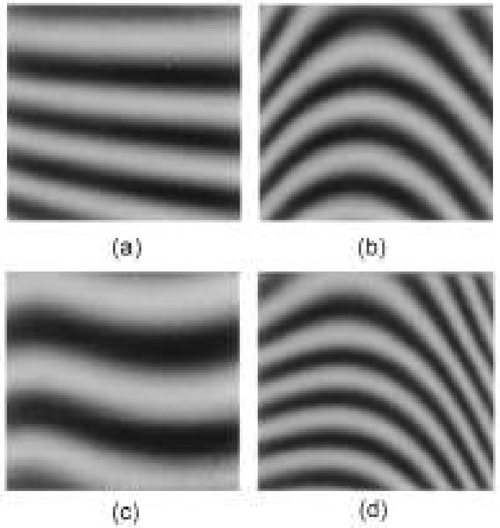


Fig. 1. Spectrally resolved white-light interferometer for group-delay measurement of dielectric mirrors. L_1, L_2, achromatic lenses; S_1, S_2, slits; M_S, sample mirror; M_R, reference mirror; G, transmission grating.



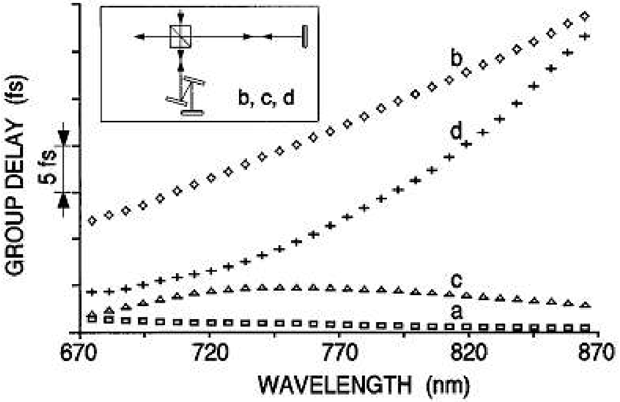


Fig. 4. Measured group-delay functions obtained by computer processing of the images shown in Fig. 3 (every fifth point is plotted). The curves correspond to a single reflection. Inset: four-reflection arrangement used for measuring curves b–d.

(a) Low dispersion sample (linear phase shift)

(b) Chirped mirror sample (quatratic phase shift)

(c) Gires-Tournois Intereferometer mirror (cubic phase shift)

(d) (c)+(d)

A.P. Kovács, K. Osvay, Zs. Bor, R. Szipőcs, Opt. Lett. 20, 788-790 (1995)

Ultrabroadband chirped mirrors for ultrafast lasers

528 OPTICS LETTERS / Vol. 22, No. 8 / April 15, 1997

Ultrabroadband chirped mirrors for femtosecond lasers

E. J. Mayer, J. Möbius, A. Euteneuer, and W. W. Rühle

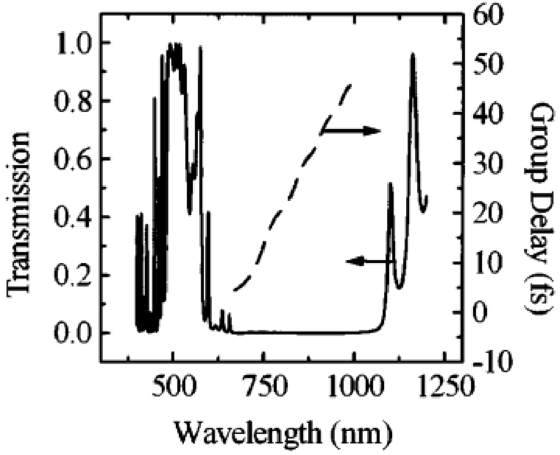
Department of Physics, Philipps University, Renthof 5, D-35032 Marburg, Germany

R. Szipőcs

R&D Lézer-Optika Bt., P.O. Box 622, H-1539 Budapest, Hungary

Received November 25, 1996

We report on the performance of widely tunable femtosecond and continuous-wave Ti:sapphire lasers that use a newly developed ultrabroadband mirror set. The mirrors exhibit high reflectivity ($R > 99\%$) and smooth variation of group delay versus frequency over a wavelength range from 660 to 1060 nm. Mode-locked operation with pulse durations of 85 fs was achieved from 693 to 978 nm with only one set of ultrabroadband mirrors. © 1997 Optical Society of America



- The first widely tunable femtosecond pulse Ti:sapphire laser
- High reflectivity (*R . 99%) and* smooth variation of group delay over a wavelength range from 660 to 1060 nm
- Mode-locked operation from 693 to 978 nm using one set of mirrors

E.J. Mayer, J. Möbius, A. Euteneuer, W. Rühle, R. Szipőcs: Opt. Lett. 22, 528-530 (1997)

Reasearch sponsored by Bilateral German-Hungarian Science and Technology Foundation (Philipps University, R&D Lézer-Optika)

PAST : R&D Ltd. / Wigner RCP and the ELI project

ULTRAFAST LASERS

High-quality seed pulses from mirror-dispersion-controlled Ti:sapphire system allow chirped pulse amplification without a pulse stretcher.

Chirped dielectric mirrors improve Ti:sapphire lasers

Ch. Spielmann, M. Lenzner, F. Krausz, R. Szipöcs, and K. Ferencz

Titanium-doped sapphire (Ti:sapphire) is probably the most successful laser medium used in ultrafast lasers because of its broad gain bandwidth (approximately 200 nm FWHM) and excellent mechanical and thermal properties. The discovery of self- or Kerr-lens mode-locking has also opened the way to an efficient exploitation of its enormous optical bandwidth for ultrashort pulse generation.[1,2]

Commercial self-modelocked Ti:sapphire lasers, offering average output powers up to 2 W and pulse durations as low as 50 fs, are now commonplace in ultrafast laboratories. The Ti:sapphire medium is also well suited for extracavity amplification, yielding high-power femtosecond pulses. Several manufacturers offer Ti:sapphire oscillator-amplifier systems that can produce pulses in the 100-fs range with terawatt peak powers and repetition rates of 10 Hz or less. Whereas these femtosecond commercial systems represent dramatic progress in terms of reliability, lifetime, and peak power, the pulse duration they offer is not significantly shorter than that available from the previous-generation, dye-laser-based systems. Nevertheless, the broad bandwidth of Ti:sapphire and the ultrafast response of the Kerr effect potentially allow the generation of substantially shorter pulses.

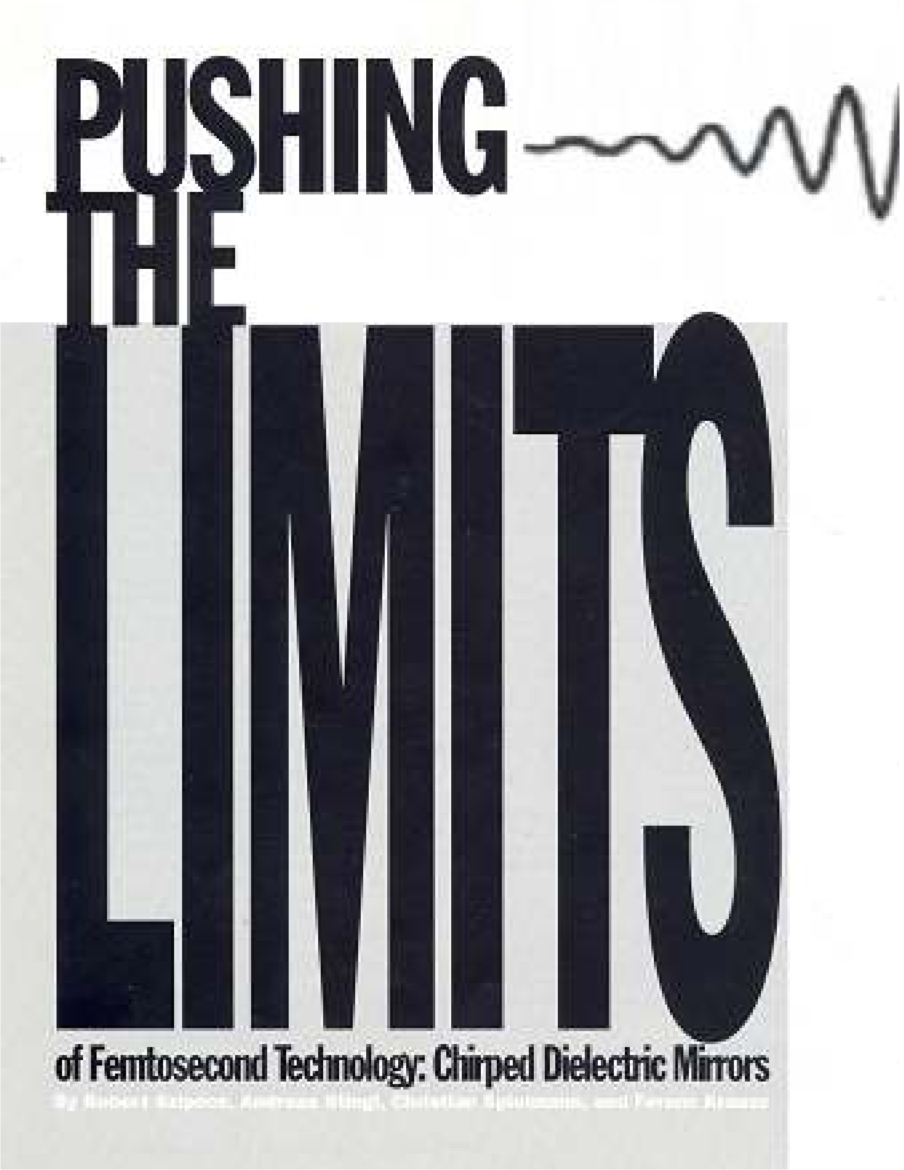
The motivation for further decreasing pulse durations comes from a number of fields. Researchers often need to achieve high powers without producing excessive pulse energies that cause damage to solid targets. In reversible optical experiments, metals, semiconductors, and insulators can be exposed to femtosecond pulses with intensities orders-of-magnitude higher than practicable with picosecond pulses. In moderate-intensity spectroscopy, pulse duration determines the achievable time resolution of pump-probe experiments.

Sub-100-fs time resolution, available since the early 1980s, is usually sufficient to "freeze" the rotational and vibrational dynamics of complex atomic systems such as molecules, clusters, and condensed matter, and even the motion of sufficiently heavy atoms in chemical processes. Microscopic dynamics, however, often take place on a time scale of roughly 10 fs or less. For instance, the study of coherent light-matter interactions, which provides information about the coupling of atoms, ions, and molecules to their surroundings, calls for sub-10-fs

Multipass Ti:sapphire amplifier is seeded with high-quality 8-fs pulses generated by a Ti:sapphire oscillator incorporating chirped dielectric mirrors for dispersion compensation.

CH. SPIELMANN and M. LENZNER are postdoctoral researchers and F. KRAUSZ is assistant professor at the Abteilung Quantenelektronik and Lasertechnik, Technische Universität (Vienna, Austria). R. SZIPÖCS is a postdoctoral researcher and K. FERENCZ is the head of the Optical Coating Laboratory at the Research Institute for Solid State Physics (Budapest, Hungary).

Laser Focus World *December 1995* [illegible]

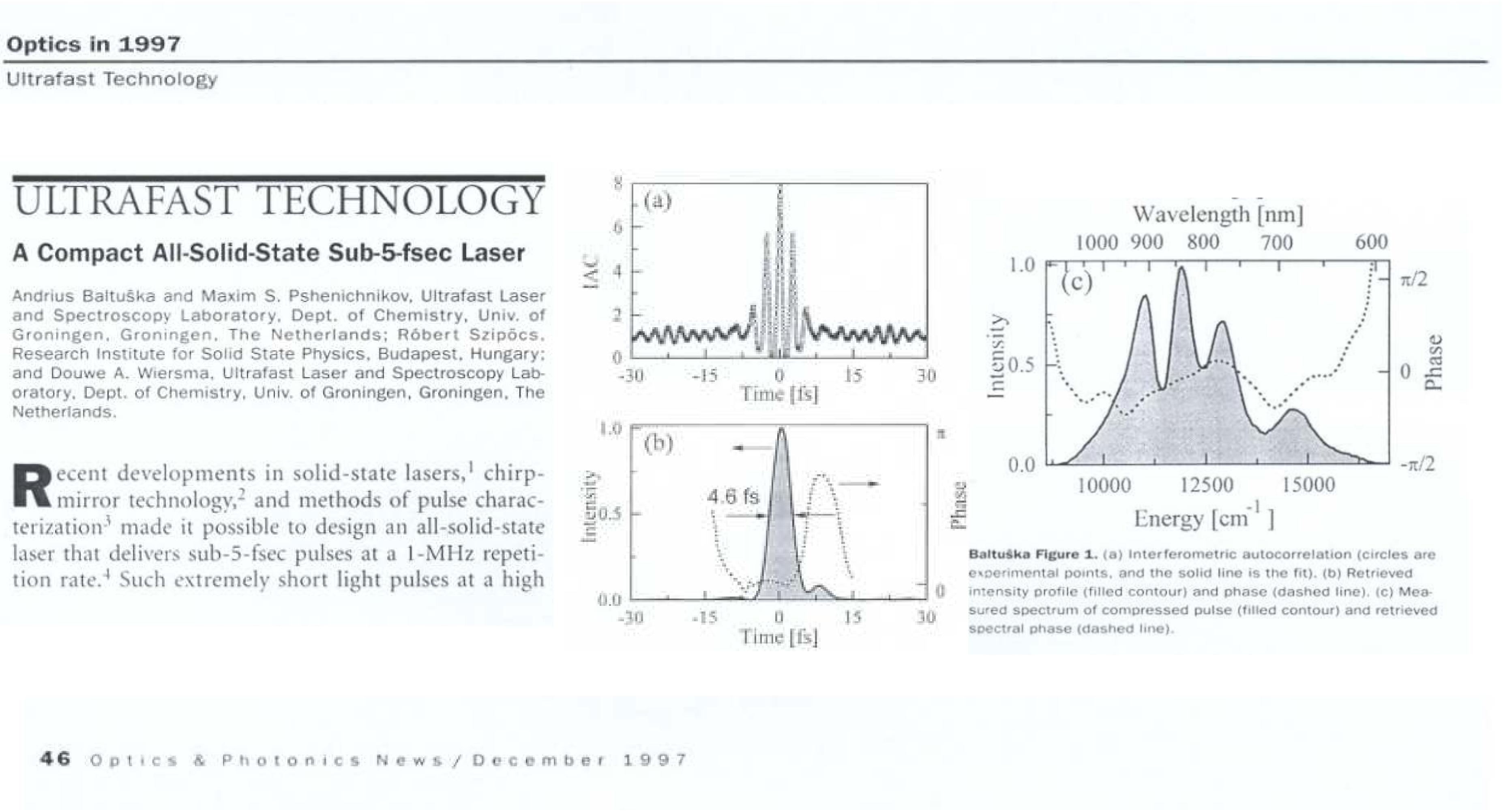


PUSHING THE LIMITS

of Femtosecond Technology: Chirped Dielectric Mirrors

By Robert Szipöcs, Andreas Stingl, Christian Spielmann, and Ferenc Krausz

Compression of laser pulses down to 4.6 fs



ULTRAFAST TECHNOLOGY

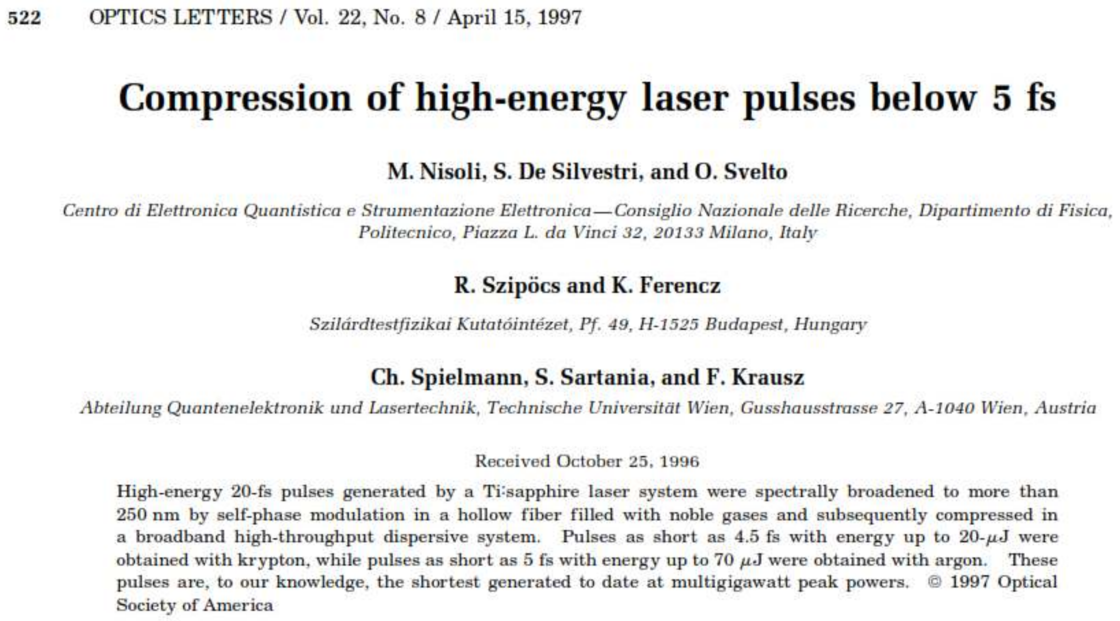
A Compact All-Solid-State Sub-5-fsec Laser

Andrius Baltuška and Maxim S. Pshenichnikov, Ultrafast Laser and Spectroscopy Laboratory, Dept. of Chemistry, Univ. of Groningen, Groningen, The Netherlands; Róbert Szipöcs, Research Institute for Solid State Physics, Budapest, Hungary; and Douwe A. Wiersma, Ultrafast Laser and Spectroscopy Laboratory, Dept. of Chemistry, Univ. of Groningen, Groningen, The Netherlands.

Recent developments in solid-state lasers,[1] chirp-mirror technology,[2] and methods of pulse characterization[3] made it possible to design an all-solid-state laser that delivers sub-5-fsec pulses at a 1-MHz repetition rate.[4] Such extremely short light pulses at a high

Baltuška Figure 1. (a) Interferometric autocorrelation (circles are experimental points, and the solid line is the fit). (b) Retrieved intensity profile (filled contour) and phase (dashed line). (c) Measured spectrum of compressed pulse (filled contour) and retrieved spectral phase (dashed line).

Compression of high-energy laser pulses below 5 fs



522 OPTICS LETTERS / Vol. 22, No. 8 / April 15, 1997

Compression of high-energy laser pulses below 5 fs

M. Nisoli, S. De Silvestri, and O. Svelto

Centro di Elettronica Quantistica e Strumentazione Elettronica—Consiglio Nazionale delle Ricerche, Dipartimento di Fisica, Politecnico, Piazza L. da Vinci 32, 20133 Milano, Italy

R. Szipöcs and K. Ferencz

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Ch. Spielmann, S. Sartania, and F. Krausz

Abteilung Quantenelektronik und Lasertechnik, Technische Universität Wien, Gusshausstrasse 27, A-1040 Wien, Austria

Received October 25, 1996

High-energy 20-fs pulses generated by a Ti:sapphire laser system were spectrally broadened to more than 250 nm by self-phase modulation in a hollow fiber filled with noble gases and subsequently compressed in a broadband high-throughput dispersive system. Pulses as short as 4.5 fs with energy up to 20-μJ were obtained with krypton, while pulses as short as 5 fs with energy up to 70 μJ were obtained with argon. These pulses are, to our knowledge, the shortest generated to date at multigigawatt peak powers. © 1997 Optical Society of America

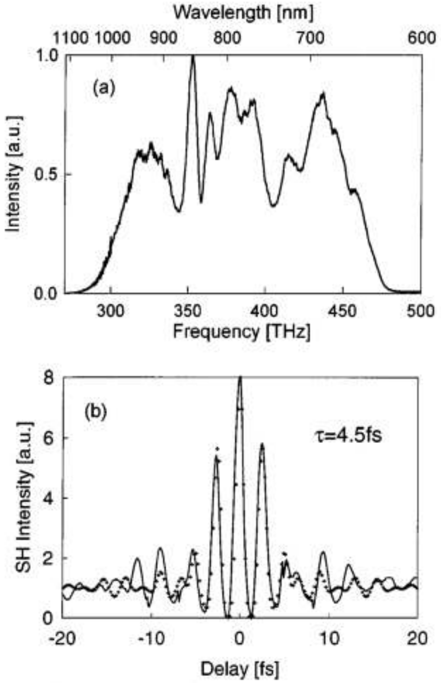

Fig. 2. (a) Spectral broadening in krypton at $p = 2.1$ bars and $P_0 = 2$ GW. A low-intensity pedestal (~1% of the peak) extends below 600 nm. (b) Measured (solid curve) and calculated (crosses) autocorrelation trace; an evaluation of the pulse duration (FWHM) is also given.

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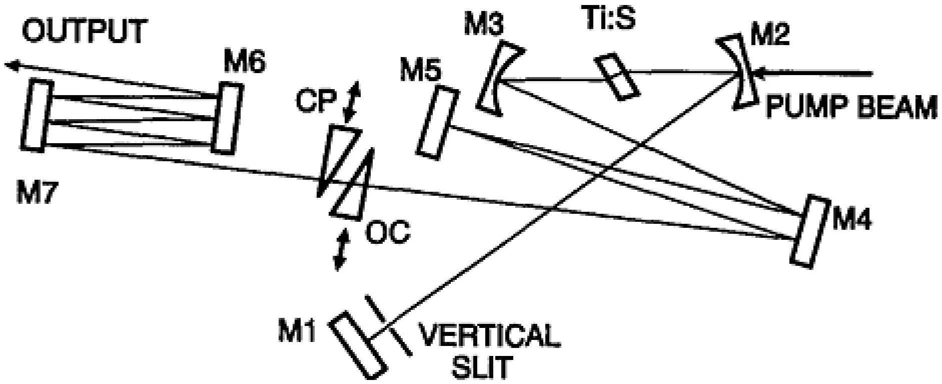
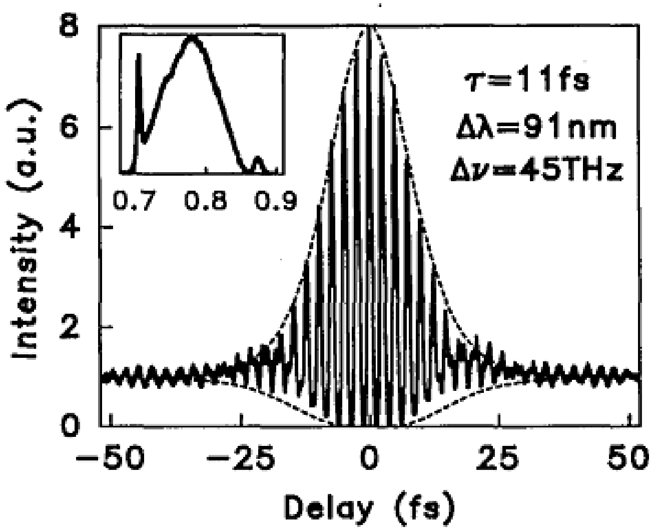
MIRROR DISPERSION CONTROLLED Ti:SAPPHIRE LASER





LINEAR CAVITY

☺ **Highly stable femtosecond pulses with duration of ~ 11fs**

A.Stingl, Ch. Spielmann, F. Krausz, R. Szipőcs, *Opt. Lett.* 19, pp. 204-206 (1994)

R. Szipőcs, F. Krausz: U. S. Pat. No.: 5,734,503 (1993)

SCIENTIFIC BACKGROUND

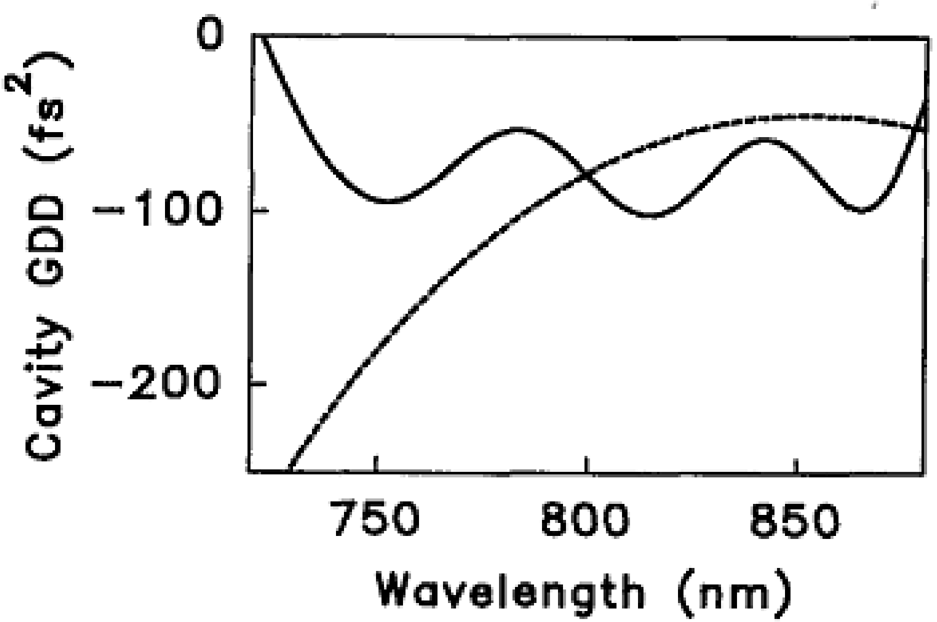
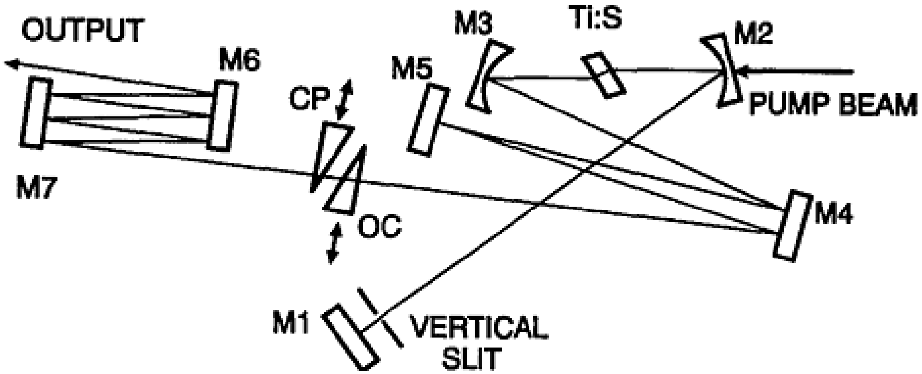
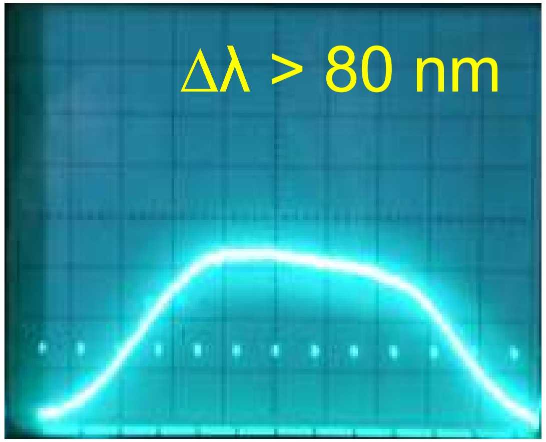


Fig. 3. Overall intracavity GDD (solid curve) versus wavelength for the system illustrated in Fig. 1. This can be compared with the dispersion curve of the same Ti:sapphire laser with a pair of fused-silica prisms (dashed curve). An assumed minimum prism insertion of 4 mm and a required nominal GDD of -80 fs^2 yielded a prism separation of 34.4 cm.

A. Stingl, Ch. Spielmann, F. Krausz, R. Szipőcs, *Opt. Lett.* 19(3), 204 (1994)

FEMTOROSE 10 MDC/PRC Ti-zafír lézer



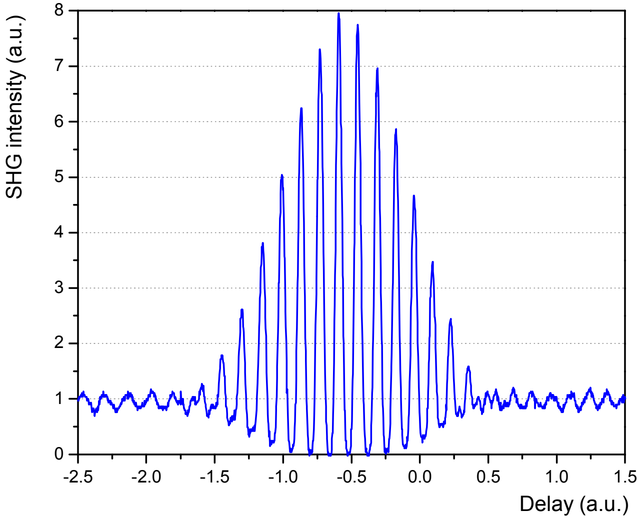


U. S. Pat. No.: 5, 734, 503

$\Delta\lambda > 80$ nm, $\Delta\tau < 10$ fs

$\Delta\nu\Delta\tau \geq 0.315$

$\Delta\tau < 10$ fs



Ultrabroadband chirped mirrors for ultrafast lasers

528 OPTICS LETTERS / Vol. 22, No. 8 / April 15, 1997

Ultrabroadband chirped mirrors for femtosecond lasers

E. J. Mayer, J. Möbius, A. Euteneuer, and W. W. Rühle

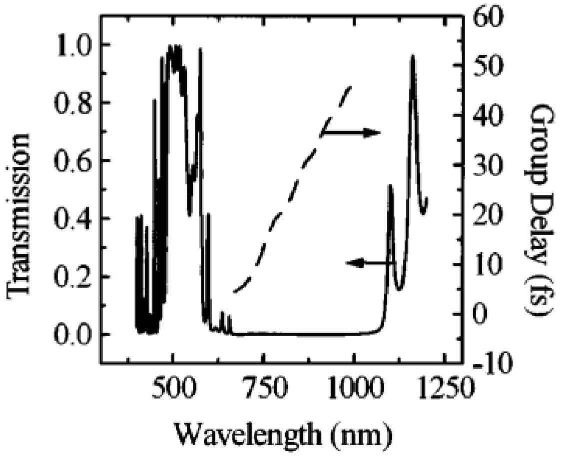
Department of Physics, Philipps University, Renthof 5, D-35032 Marburg, Germany

R. Szipőcs

R&D Lézer-Optika Bt., P.O. Box 622, H-1539 Budapest, Hungary

Received November 25, 1996

We report on the performance of widely tunable femtosecond and continuous-wave Ti:sapphire lasers that use a newly developed ultrabroadband mirror set. The mirrors exhibit high reflectivity ($R > 99\%$) and smooth variation of group delay versus frequency over a wavelength range from 660 to 1060 nm. Mode-locked operation with pulse durations of 85 fs was achieved from 693 to 978 nm with only one set of ultrabroadband mirrors. © 1997 Optical Society of America

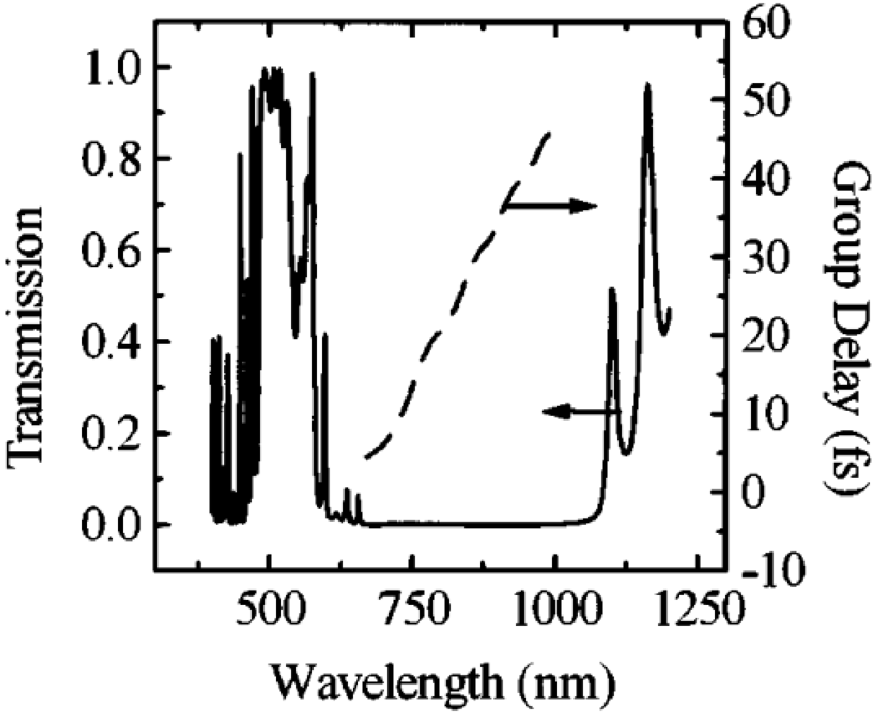


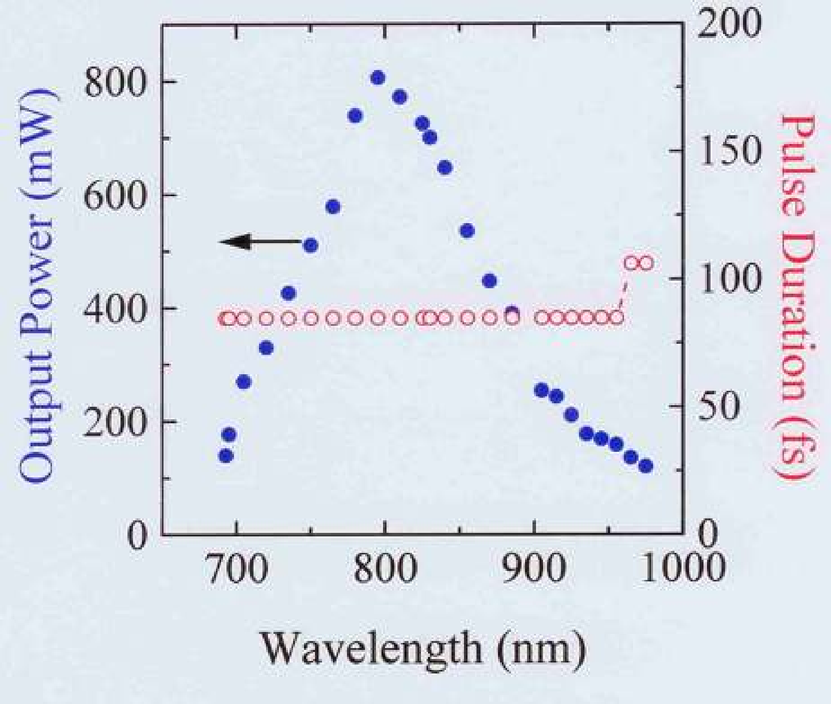
- **The first widely tunable femtosecond pulse Ti:sapphire laser!**
- High reflectivity (*R . 99%) and* smooth variation of group delay over a wavelength range from 660 to 1060 nm
- Mode-locked operation from 693 to 978 nm using one set of mirrors

E.J. Mayer, J. Möbius, A. Euteneuer, W. Rühle, R. Szipőcs: Opt. Lett. 22, 528-530 (1997)

Reasearch sponsored by Bilateral German-Hungarian Science and Technology Foundation (Philipps University, R&D Lézer-Optika)

Széles sávban hangolható < 100 fs-os Ti-zafír lézer kifejlesztése





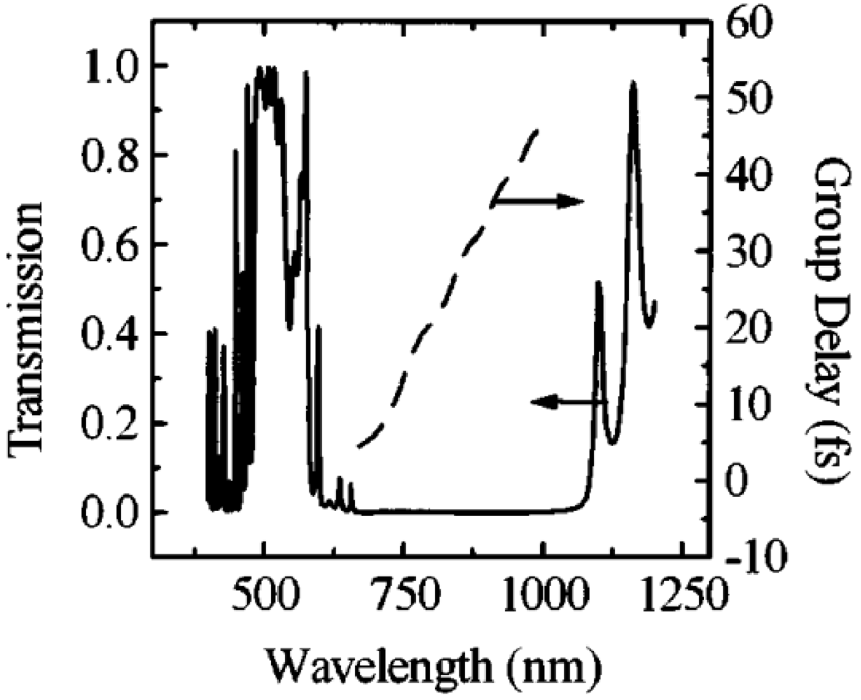
- **Ultraszélessávú csörpölt tükrök (HR tartomány: 660-1060 nm)**
- **Széles hangolási tartomány tükörkészlet cseréje nélkül (693-978 nm)**

E.J. Mayer, J. Möbius, A. Euteneuer, W. Rühle, R. Szipőcs: Opt. Lett. 22, 528-530 (1997).

Reasearch sponsored by Bilateral German-Hungarian Science and Technology Foundation (Philipps University, R&D Lézer-Optika)

Széles sávban hangolható < 100 fs-os Ti-zafír lézer: alkalmazások a nemlineáris mikroszkópiában

„Broadband Optics with **I**-track Extend the Reach of Multiphoton Microscopy”



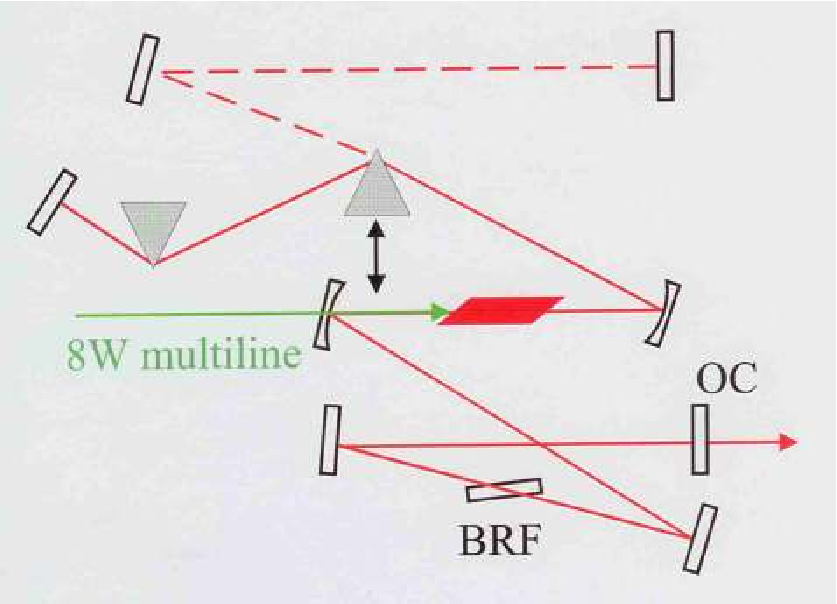
Spectra-Physics
The Solid State Laser Company™

E.J. Mayer, J. Möbius, A. Euteneuer, W. Rühle, **R. Szipőcs**: Opt. Lett. 22, 528-530 (1997).

Reasearch sponsored by Bilateral German-Hungarian Science and Technology Foundation (Philipps University, R&D Lézer-Optika)

FEMTOROSE 100 TUN Ti-zafír lézer

A FemtoRose 100TUN NT Ti-zafír lézer felépítése



BRF: kettőstörő szűrő, OC: nyitótükör

E.J. Mayer, J. Möbius, A. Euteneuer, W. Rühle, R. Szipőcs: Opt. Lett. 22, 528-530 (1997).

Széles sávban hangolható < 100 fs-os Ti-zafír lézer

FemtoRose 100 TUN Compact, NoTouch (10W pump)

NEW! Our latest version of femtosecond pulse Ti:sapphire laser developed for nonlinear 3D microscopy

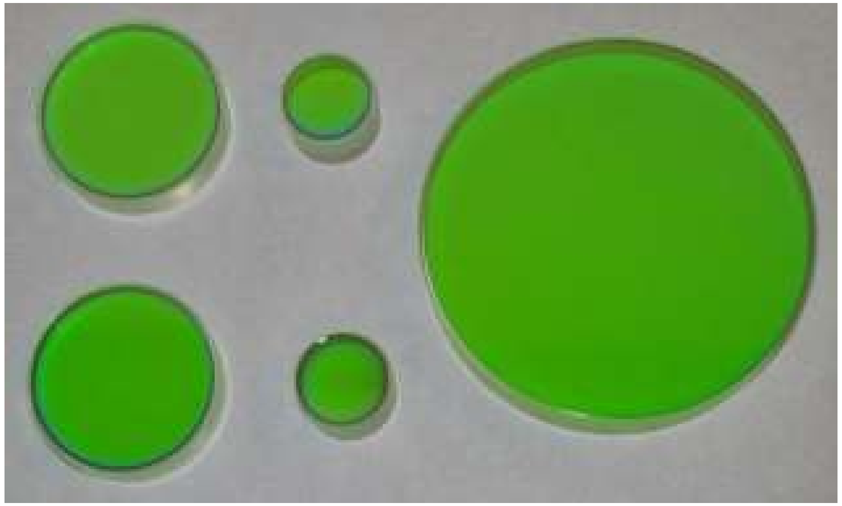
FemtoRose 100 TUN Compact/NoTouch (TM)
- tuning range 690 to 1050 nm
- patented ultrabroadband chirped mirror (UBCM) technology
- internal shutter (can be operated directly by the microscope)
- wavelength setting by a computer or a microscope
- compatible with Carl Zeiss microscopes (ZEN software)
- internal pump laser
- fully closed housing, operation is independent of environmental conditions (e.g., humidity)

R&D Ultrafast Lasers Ltd – your partner in nonlinear 3D microscopy

Other related products and services:
- ion beam sputtered, low dispersion or dispersion compensating mirrors
- building complete laser-optical laboratories
- consulting
- service for femtosecond pulse laser system

R&D Ultrafast Lasers Research and Development Ltd.
H-1012 Budapest, Attila út. 73.
KFKI Campus: H-1121 Budapest,
Konkoly Thege út. 29-33, Building 6, Floor 1
Phone/Fax: +36 1 392 2582 | E-mail: r.szipocs@szipocs.com
WEB site: www.fslasers.com

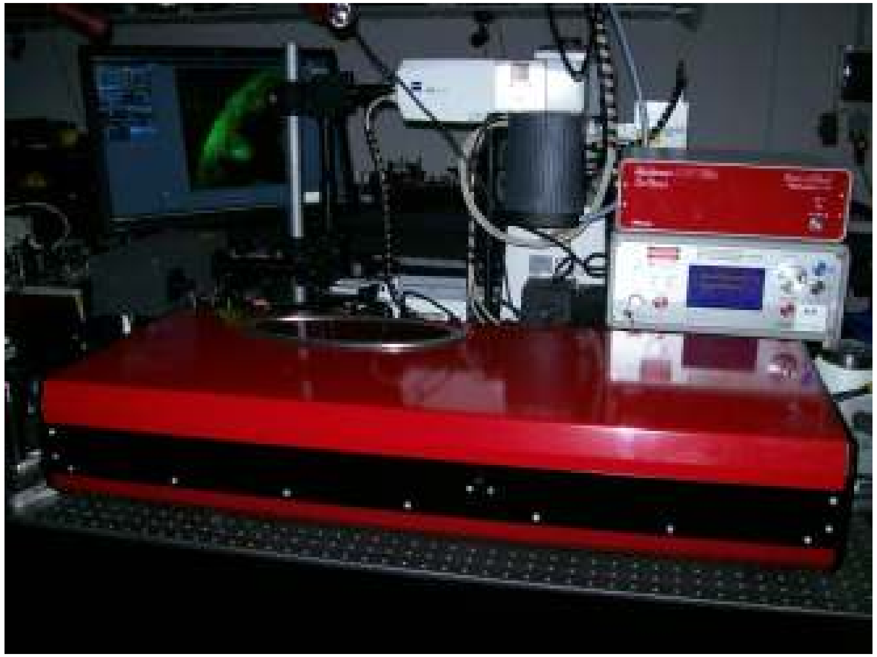
Ultraszélessávú, ionosan porlasztott csörpölt tükrök biztosítják a lézerben a széles sávban való hangolhatóságot



HR tartomány: 660 - 1060 nm

FemtoRose 100 TUN/NoTouch

the
Broadly Tunable, femtosecond pulse Ti:sapphire laser

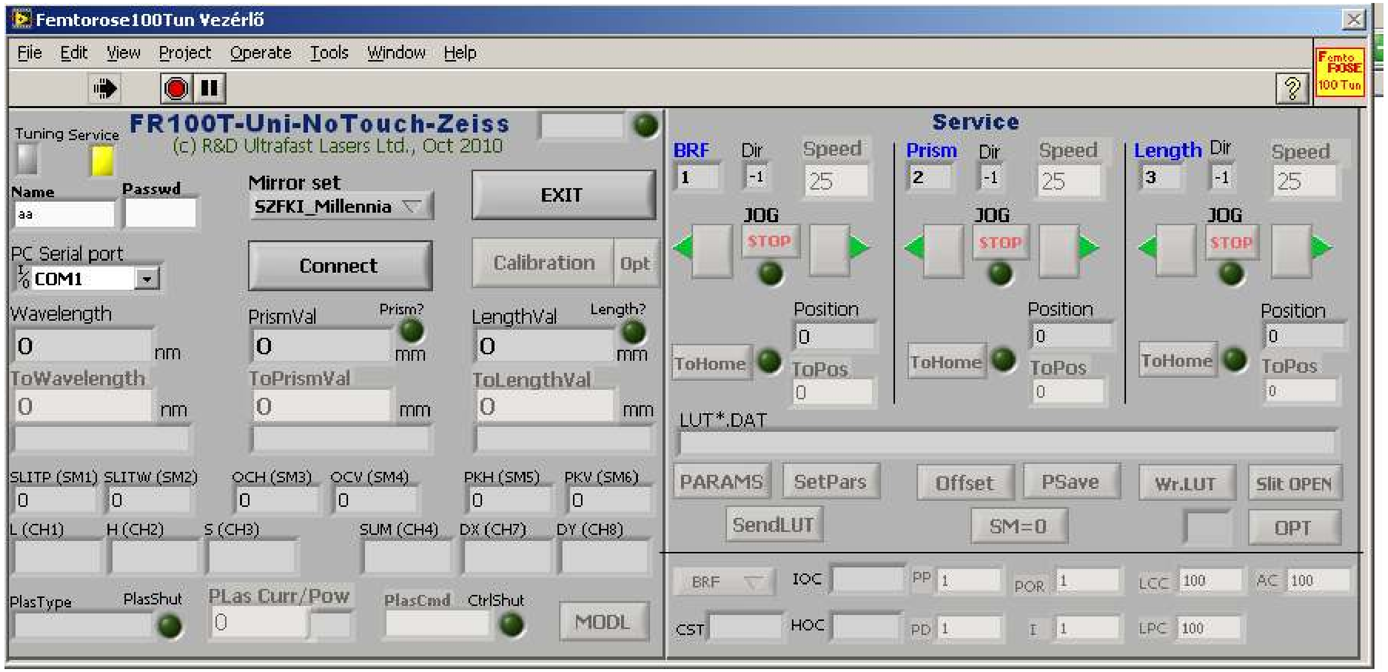


- Stable, easy mode-locking (with starter electronics)
- Soliton-like, nearly transform-limited pulses
- Patented Ultrabroadband Chirped Mirror™ optics
  - single optics set from 680 to 1040 nm
- Built in Millennia™ / Verdi™ / Finesse™ pumping (6W, 8W, 10W) – diode-pumped stability
- Sealed, purgeable enclosure
  - reliability, full wavelength coverage
- 15 years of experience
- Labview interface program
- Turn-key, truly hands-off operation (automatic cavity control)

Development (NoTouch option) partially sponsored by BAROSS-KM07-KM-TERM-07_2008-003 project (R&D Ultrafast Laserrs Ltd.)

LASER CONTROL

STEP and DC micromotor drivers, SW
Photodiodes, quadrant detectors for beam position sensing
PIC and ARM microcontrollers



Femtorose100Tun Vezérlő

FR100T-Uni-NoTouch-Zeiss
(c) R&D Ultrafast Lasers Ltd., Oct 2010

Name: aa
Mirror set: SZFKI_Millennia
PC Serial port: COM1
Wavelength: 0 nm
ToWavelength: 0 nm
PrismVal: 0 mm
ToPrismVal: 0 mm
LengthVal: 0 mm
ToLengthVal: 0 mm
SLITP (SM1): 0
SLITW (SM2): 0
OCH (SM3): 0
OCV (SM4): 0
PKH (SM5): 0
PKV (SM6): 0
PLas Curr/Pow: 0
BRF: 1, Dir: -1, Speed: 25, Position: 0, ToPos: 0
Prism: 2, Dir: -1, Speed: 25, Position: 0, ToPos: 0
Length: 3, Dir: -1, Speed: 25, Position: 0, ToPos: 0
PP: 1
POR: 1
LCC: 100
AC: 100
PD: 1
I: 1
LPC: 100

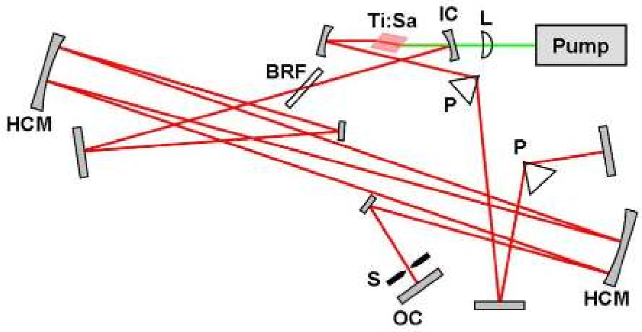
Development (NoTouch option) partially sponsored by BAROSS-KM07-KM-TERM-07_2008-003 project (R&D Ultrafast Laserrs Ltd.)

ÚJ FEJLESZTÉSI EREDMÉNYÜNK:
Hangolható, femtoszekundumos, hosszúrezonátoros Ti-zafír lézer

FemtoRose 300 TUN/NoTouch

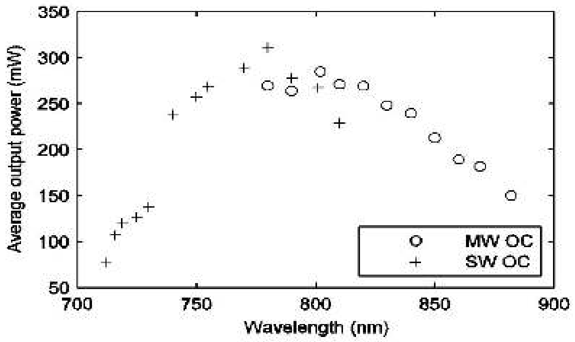
The Concept

Schematic of the oscillator



L: pump focusing lens, **IC:** input coupler mirror, **Ti:Sa:** titanium-sapphire crystal, **BRF:** birefringent filter for tuning, **P:** prisms, **HCM:** Herriott-cell mirrors, **OC:** output coupler, **S:** slit for hard-aperture KLM

Typical measured output power vs. wavelength (at 2.6 W pump)



Two different output couplers were used for short wavelengths (SW OC, crosses) and for longer wavelengths (MW OC, circles).

Antal P, Szipőcs R; Tunable, low-repetition-rate, cost-efficient femtosecond Ti:sapphire laser for nonlinear microscopy; Appl Phys B; 107; 17–22, 2012

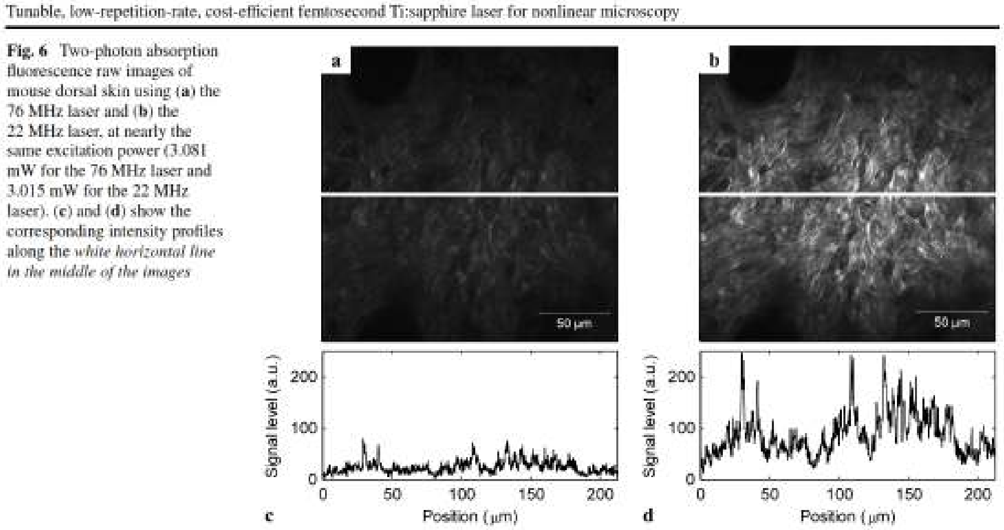
Development sponsored by BAROSS-KM07-KM-TERM-07_2008-003 project (R&D Ultrafast Laserrs Ltd.)

FemtoRose 300 TUN/NoTouch

Low Average Power, High Quality Imaging in Two-Photon Microscopy

Előnyök:

- **Olcsóbb pumpáló lézer (532 nm, max. 4 W) kell !**
- **Jobb képminőség (jel/zaj arány) ugyanannál az átlagteljesítménynél**



Tunable, low-repetition-rate, cost-efficient femtosecond Ti:sapphire laser for nonlinear microscopy

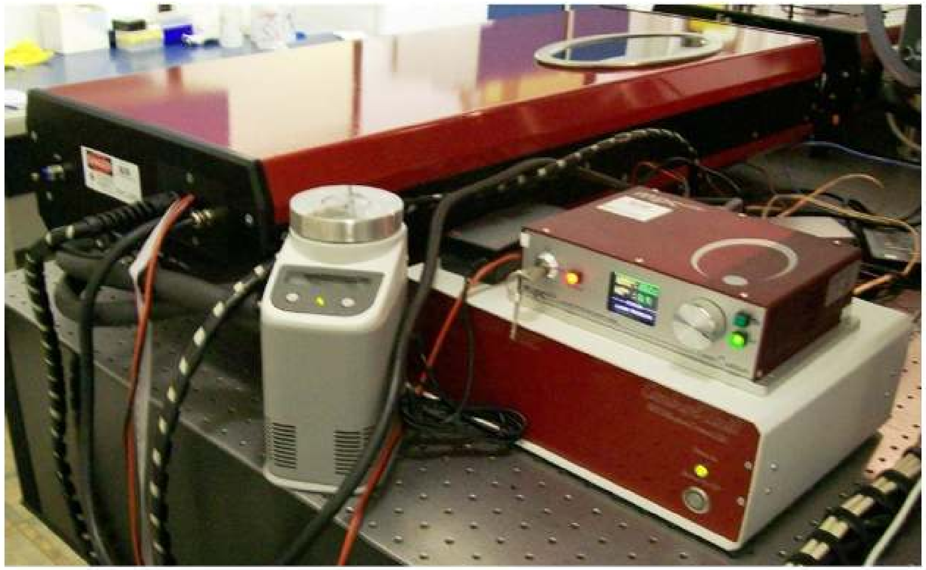
Fig. 6 Two-photon absorption fluorescence raw images of mouse dorsal skin using (**a**) the 76 MHz laser and (**b**) the 22 MHz laser, at nearly the same excitation power (3.081 mW for the 76 MHz laser and 3.015 mW for the 22 MHz laser). (**c**) and (**d**) show the corresponding intensity profiles along the *white horizontal line in the middle of the images*

Antal P, Szipőcs R; Tunable, low-repetition-rate, cost-efficient femtosecond Ti:sapphire laser for nonlinear microscopy; Appl Phys B; 107; 17–22, 2012

Development sponsored by BAROSS-KM07-KM-TERM-07_2008-003 project (R&D Ultrafast Laserrs Ltd.)

FemtoRose 300 TUN/NoTouch

The Cost Efficient Long-Cavity, Broadly Tunable, femtosecond pulse Ti:sapphire laser



Key features

- Low pump laser cost (~ 2.6 W pumping)
- Low, 22 MHz repetition rate
- Higher fluorescence signal
- Lower thermal damage in sample
- No extra-cavity chirp control is required
- Wavelength control by a Zeiss 2P microscope

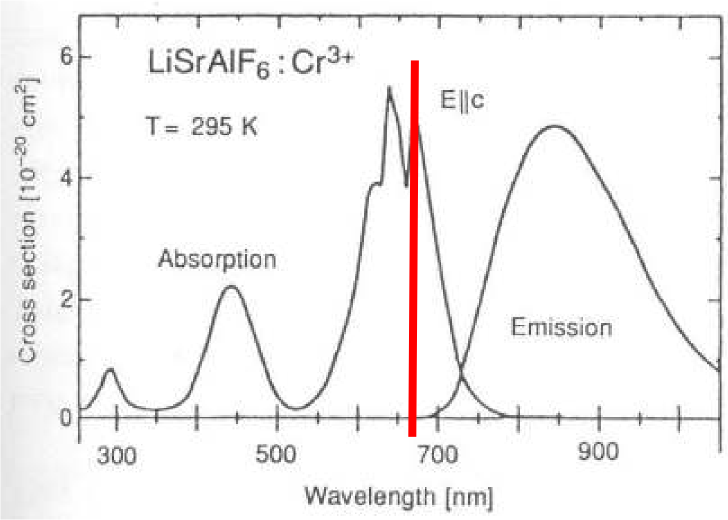
Applications

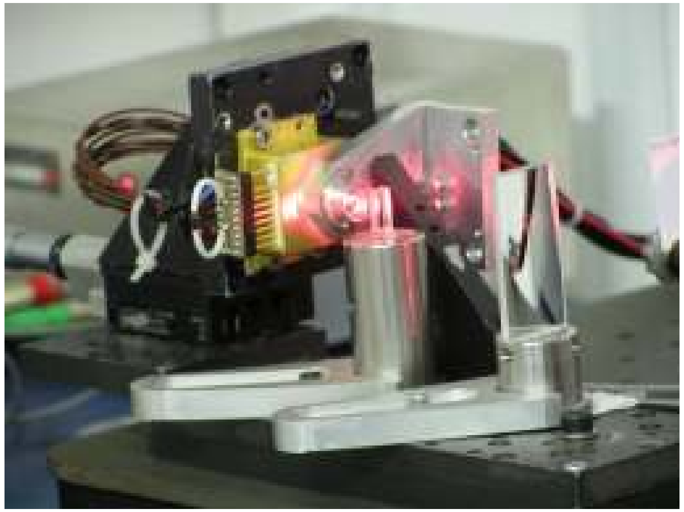
- Multiphoton microscopy
- Ultrafast spectroscopy

Development sponsored by BAROSS-KM07-KM-TERM-07_2008-003 project (R&D Ultrafast Laserrs Ltd.)

Diódapumpált, tükörkompenzált fs-os Cr:LISAF lézer

Erősítő közeg: Cr:LISAF kristály



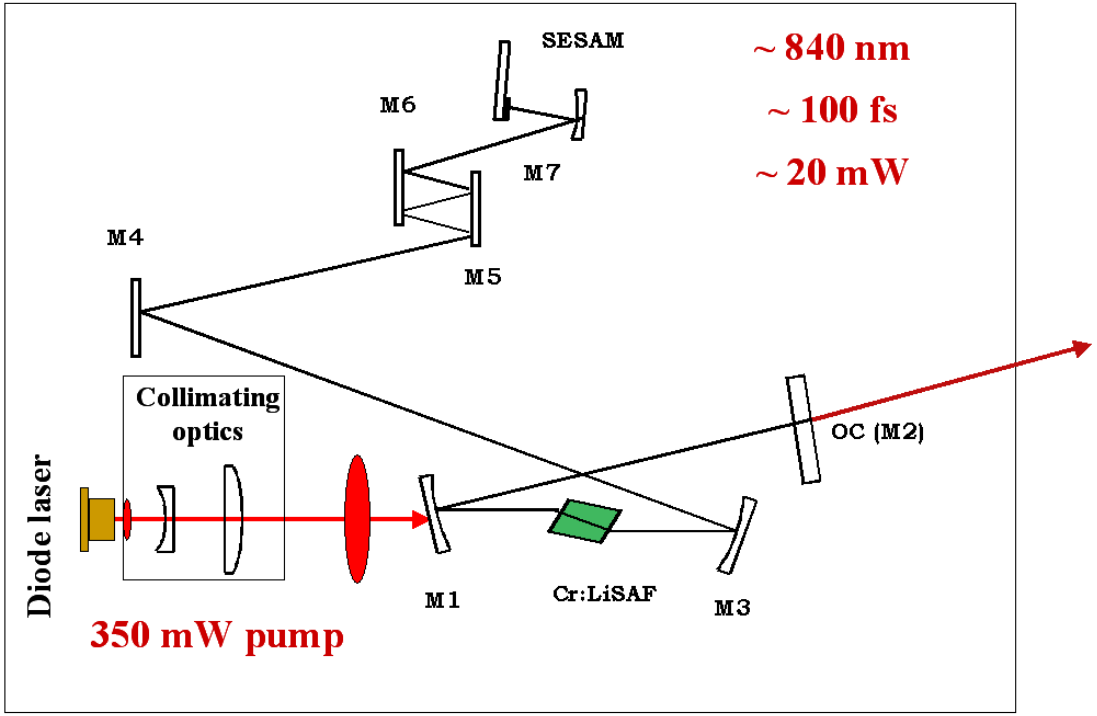


- Optikai pumpálás 670 nm-es lézerdiódával, P = 350 mW teljsítménnyel (!)
- Módusszinkronizálás félvezető telítődő abszorbens (SESAM) alkalmazásával

B. Császár, A. Kőházi-Kis, R. Szipőcs: **Low reflection loss ion-beam sputtered negative dispersion mirrors with MCGTI structure for low pump threshold, compact femtosecond pulse lasers** In *Proc. Advanced Solid State Photonics, February 6-9, 2005, Vienna, Austria* (2005), Paper WB17

Development sponsored by MUNKA00037/2003 project (R&D Ultrafast Laserrs Ltd.)

A diódapumpált Cr:LISAF lézer felépítése

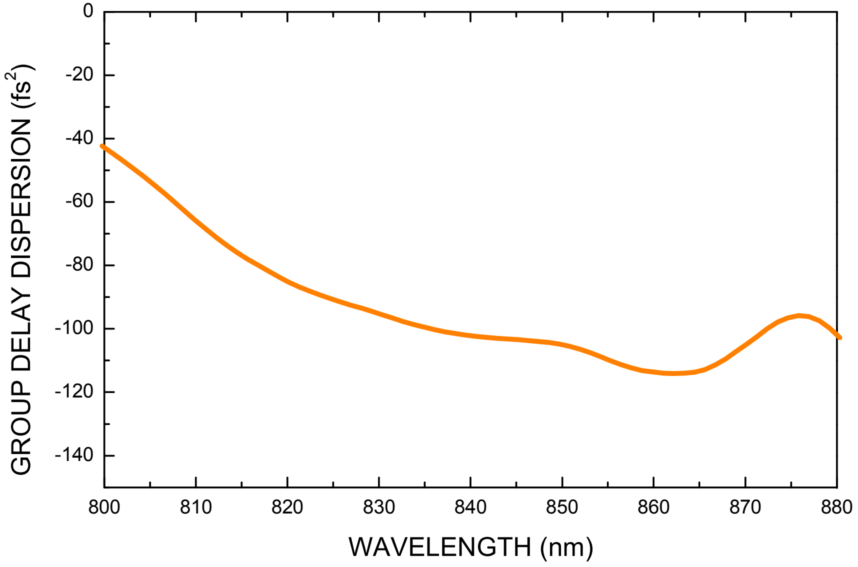


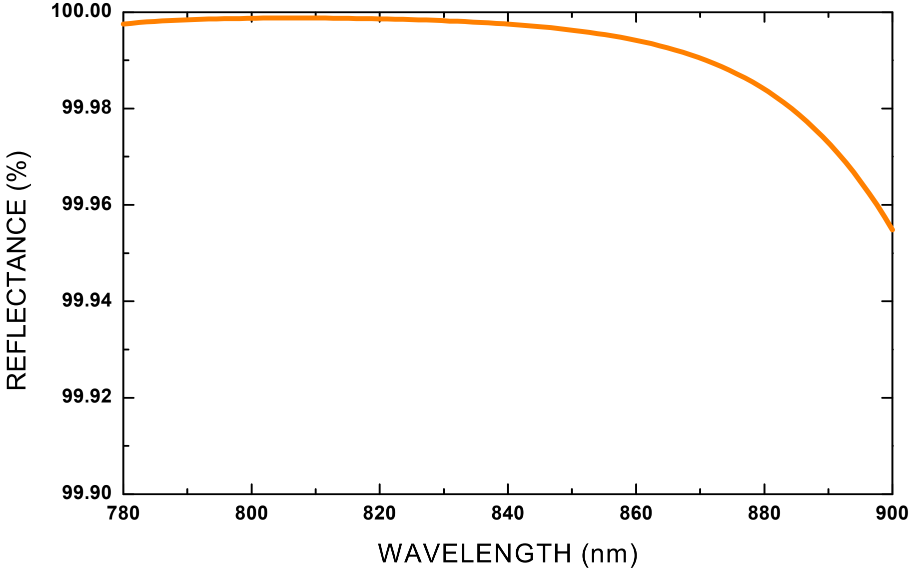
B. Császár, A. Kőházi-Kis, R. Szipőcs: **Low reflection loss ion-beam sputtered negative dispersion mirrors with MCGTI structure for low pump threshold, compact femtosecond pulse lasers** In *Proc. Advanced Solid State Photonics, February 6-9, 2005, Vienna, Austria* (2005), Paper WB17

Development sponsored by MUNKA00037/2003 project (R&D Ultrafast Laserrs Ltd.)

Diszperzió kompenzálás:

extrém kis veszteségű, **ionosan porlasztott** MCGTI tükrökkel





B. Császár, A. Kőházi-Kis, R. Szipőcs: **Low reflection loss ion-beam sputtered negative dispersion mirrors with MCGTI structure for low pump threshold, compact femtosecond pulse lasers** In *Proc. Advanced Solid State Photonics, February 6-9, 2005, Vienna, Austria* (2005), Paper WB17

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Diszperzió kompenzálás:

extrém kis veszteségű, ionosan porlasztott MCGTI tükrökkel

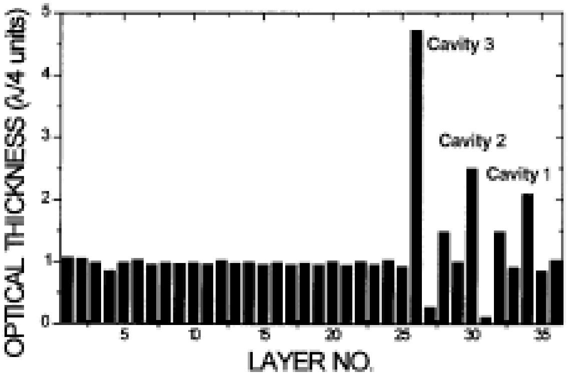
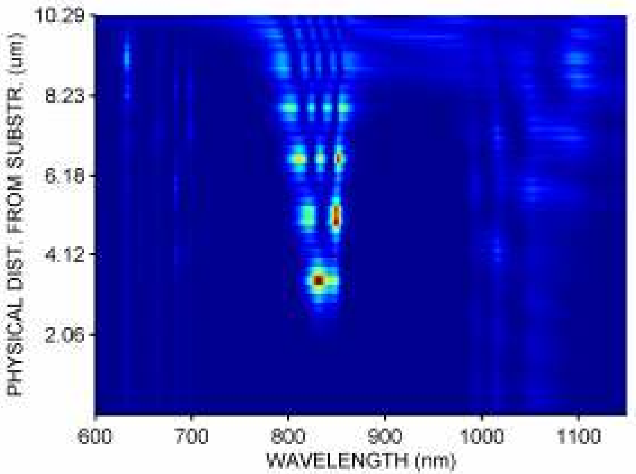


Fig. 9. Optical layer thickness coefficients of a multi-cavity thin-film Gires–Tournois interferometer. The design provides high-order dispersion-free negative GDD over a bandwidth of 56 THz with theoretical reflectivities higher than 99.97%. Even and odd layers stand for SiO_2 and TiO_2 layers, respectively



R. Szipőcs et al: **Negative dispersionmirrors for dispersion control in femtosecond lasers: chirped dielectric mirrors and multi-cavity Gires–Tournois interferometers,** Appl. Phys. B 70 [Suppl.], S51–S57 (2000)

B. Császár, A. Kőházi-Kis, R. Szipőcs: **Low reflection loss ion-beam sputtered negative dispersion mirrors with MCGTI structure for low pump threshold, compact femtosecond pulse lasers** In *Proc. Advanced Solid State Photonics, February 6-9, 2005, Vienna, Austria* (2005), Paper WB17

Nemlineáris frekvenciakonverzió szinkronpumpált optikai parametrikus oszcillátorban

IR OPO KTP kristállyal és csörpölt tükrökkel

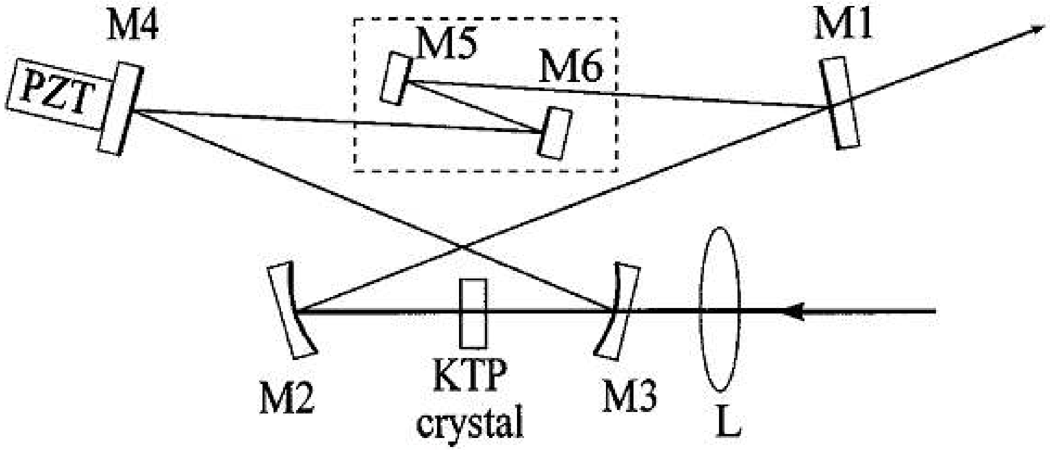
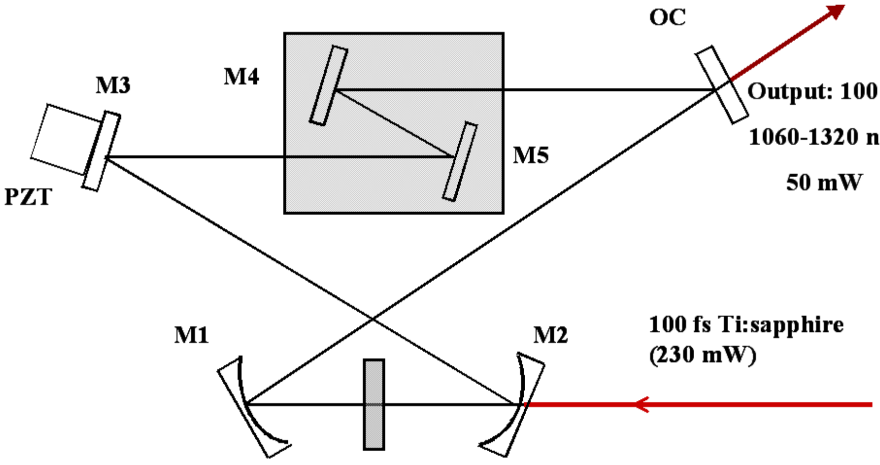
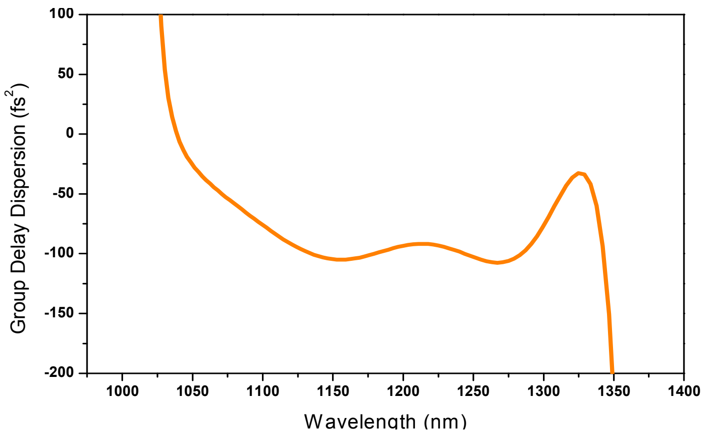


Fig. 1. Setup for the OPO.

J. Hebling, E. J. Mayer, J. Kuhl, R. Szipőcs:
”Chirped-mirror dispersion-compensated optical parametric oscillator”,
Optics Letters 20 (8), 919-921 (1995)

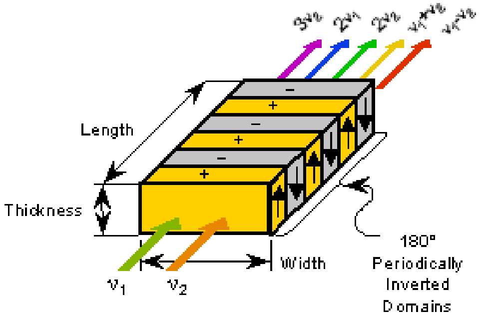
IR OPO PPLN kristállyal és MCGTI tükrökkel





Hangolási tartomány: 1060-1320 nm

Az OPO hangolása független a pumpa hullámhossztól



Sándor P, Makai A, Szipőcs R, "Szélessávú femtoszekundumos PPLN OPO időfelbontásos lézerspektroszkópiai vizsgálatokhoz" Kvantumelektronika 2008, , 6. Országos Kvantumelektronikai Konferencia, 2008. október 17, Budapest, Eds: Péter Á, Kiss T, Varró S, P-35 (2008)

Sándor Péter: Femtoszekundumos időfelbontásos lézerspektroszkópiai mérőrendszer fejlesztése (Diplomamunka, BME, 2008)

Development sponsored by GVOP-3.3.3-05/1-0078/3.0 project (R&D Ultrafast Laserrs Ltd.)

FemtoRainbow 100 OPO

Femtosecond tunable synchronously pumped optical parametric oscillator

- *Ti:Sapphire laser wavelength conversion*
- *Synchronously pumped at ~76 MHz*
- *Output is widely tunable from 1010 to 1260 nm*
- *Output power from up to 100 mW*
- *15 nm to 30 nm spectral width (FWHM)*
- *KTP or PPLN crystal based conversion*
- *Wavelength stabilization by computer control*

Az OPO hangolása független a pumpa hullámhossztól

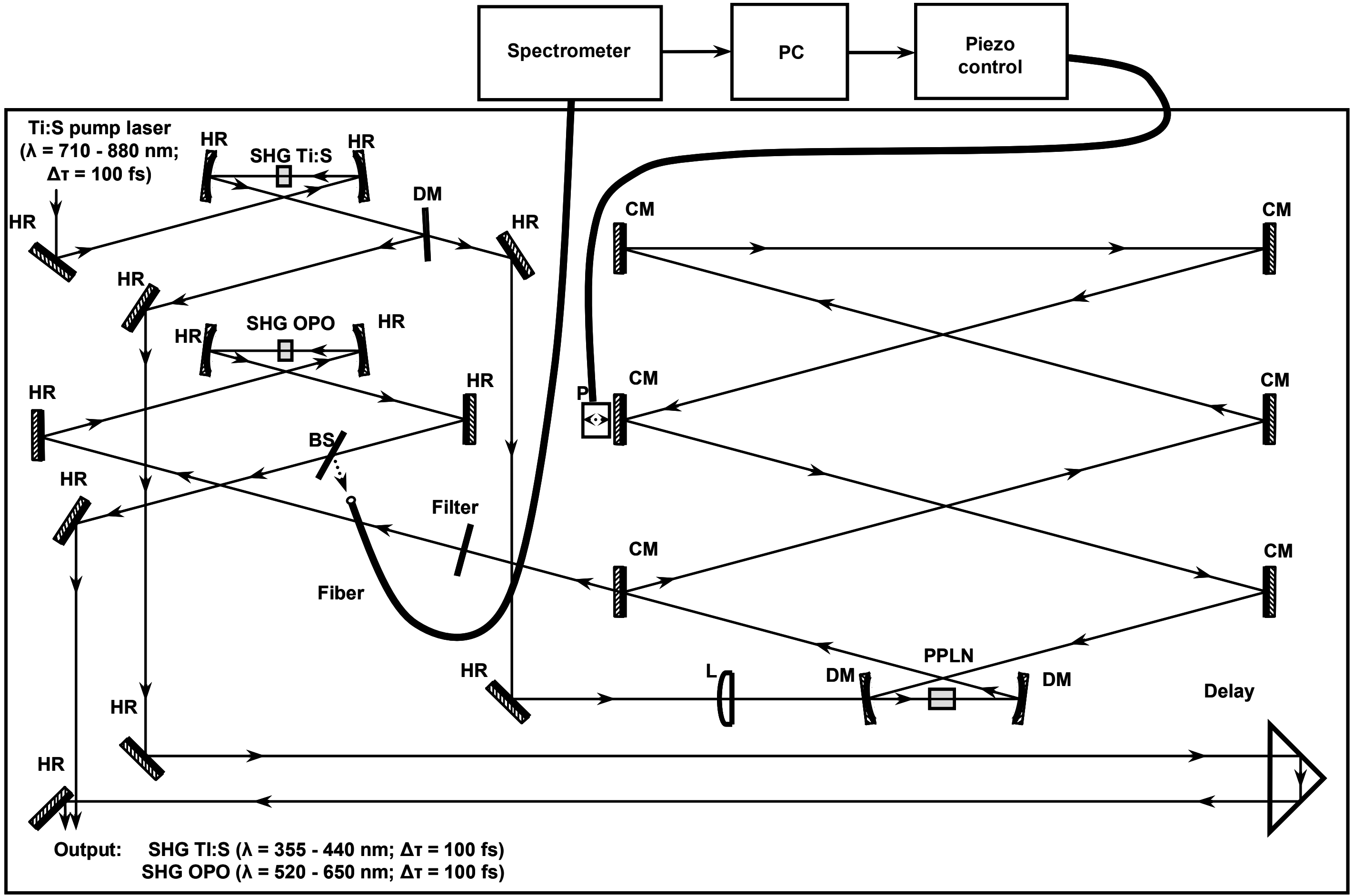
Sándor P, Makai A, Szipőcs R, "Szélessávú femtoszekundumos PPLN OPO időfelbontásos lézerspektroszkópiai vizsgálatokhoz" Kvantumelektronika 2008, , 6. Országos Kvantumelektronikai Konferencia, 2008. október 17, Budapest, Eds: Péter Á, Kiss T, Varró S, P-35 (2008)

Sándor Péter: Femtoszekundumos időfelbontásos lézerspektroszkópiai mérőrendszer fejlesztése (Diplomamunka, BME, 2008)

Development sponsored by GVOP-3.3.3-05/1-0078/3.0 project (R&D Ultrafast Laserrs Ltd.)

PPLN OPO és SHG egység

időfelbontésos lézerspektroszkópiai (pumpa-próba) mérésekhez



Legends: DM – dichroic mirror; L – lens; Fiber – multimode optical fiber; CM – chirped mirrors; P – piezo translator; PPLN – periodically poled lithium niobate; HR – high reflector; Filter – color filter; SHG – second-harmonic generation; Delay – delay line; BS – beam splitter

Femtoszekundumos lézerfizika, száloptika és nemlineáris mikroszkópia kutatócsoport

Szipőcs Group

Development sponsored by GVOP-3.3.3-05/1-0078/3.0 project (R&D Ultrafast Laserrs Ltd.)

Szálintegrált, femtoszekundumos AND Yb-szállézer

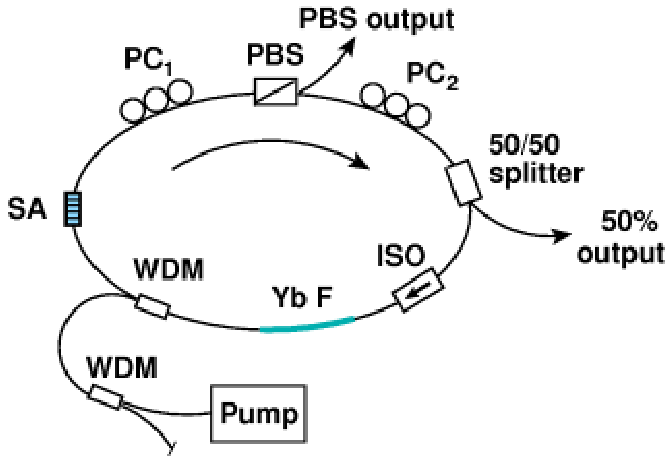
Femtobiológia projekt: R&D Ultrafast Lasers Kft, Furukawa Electric (FETI) közös laboratórium

J. Fekete, A. Cserteg, Szipőcs; **All-fiber, all-normal dispersion ytterbium ring oscillator,** Laser Physics Letters 6, 49-53, 2009

Development sponsored by NKFP1-00007/2005 project (R&D Ultrafast Laserrs Ltd., Furukawa Electric Ltd)

All-fiber, all-normal dispersion ytterbium ring oscillator

- Operation determined by interplay between **gain**, **self-phase modulation**, **dispersion** and **filtering** effects
- Pulse shaping is based on **nonlinear polarization rotation** in the fiber together with **spectral and temporal filtering** by a polarizing element



PC: polarization controller

PBS: polarizing beam splitter

ISO: isolator

Yb F: Ytterbium doped fiber

WDM: wavelength division multiplexer

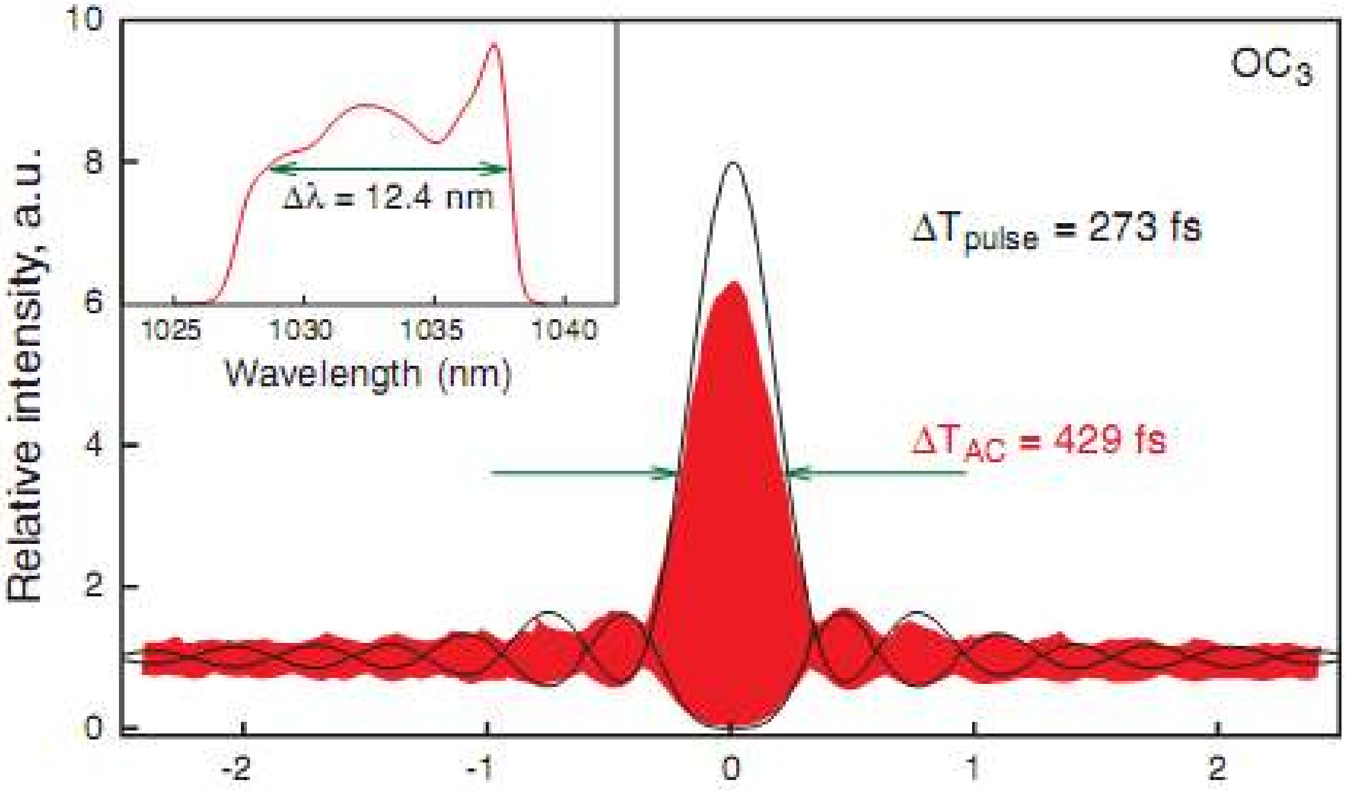
SA: saturable absorber

J. Fekete, A. Cserteg, Szipőcs; All-fiber, all-normal dispersion ytterbium ring oscillator, Laser Physics Letters 6, 49-53, 2009

Research and development sponsored by NKFP1-00007/2005 project (R&D Ultrafast Laserrs Ltd., Furukawa Electric Ltd)

Szálintegrált, femtoszekundumos AND Yb-szállézer

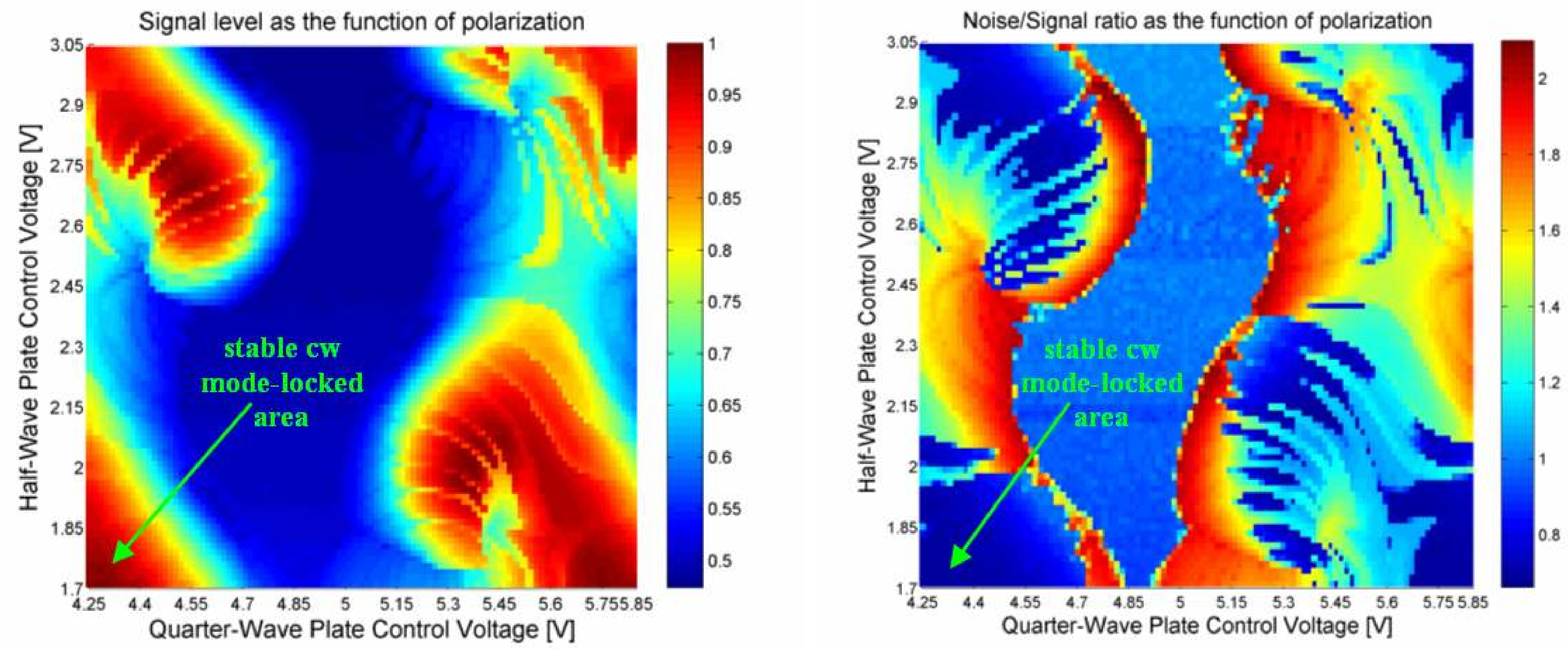
Mért jellemzők: spektrális sávszélesség és impulzushossz



J. Fekete, A. Cserteg, Szipőcs; All-fiber, all-normal dispersion ytterbium ring oscillator, Laser Physics Letters 6, 49-53, 2009

Research and development sponsored by NKFP1-00007/2005 project (R&D Ultrafast Laserrs Ltd., Furukawa Electric Ltd)

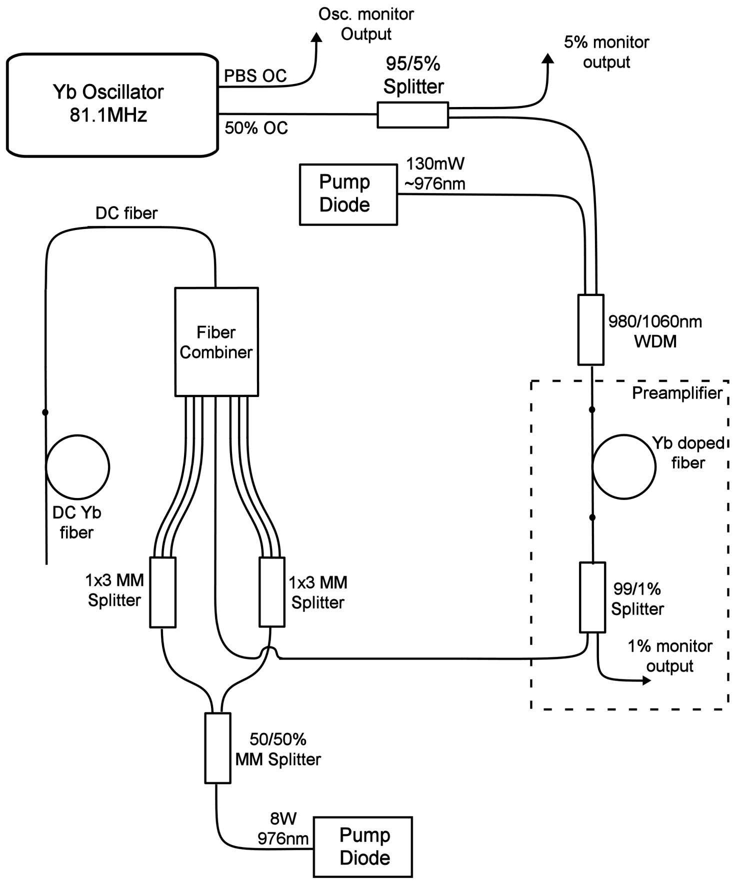
Recording of „stability maps” using SLH circuits

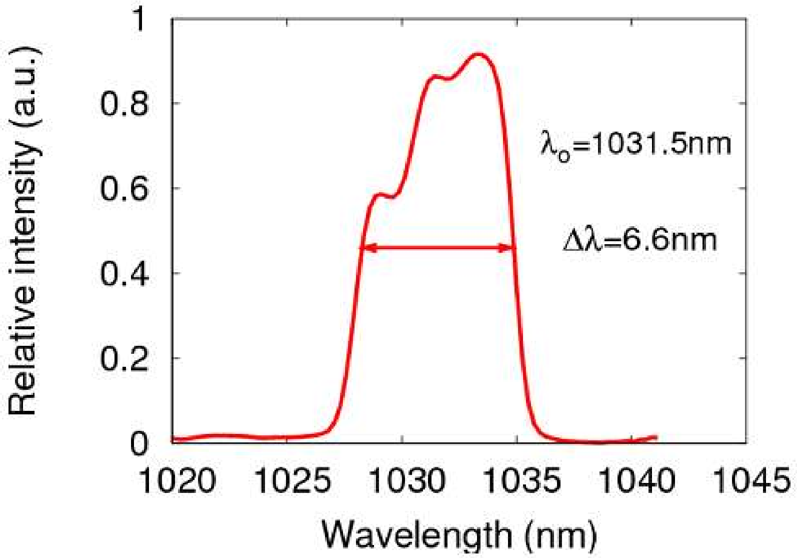


Measured signal power (left) and normalized noise power (right) as the function of control voltage on the polarization controllers.

Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)

Yb szálerősítő felépítése




Mért bemeneti spektrum

P_{osc} ~ 2-5 mW

P_{preamp} ~ 40-60 mW

P_{amp} ~ 600 - 900 mW

τ ~ 300-400 fs (kompresszált)

Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)

FemtoFiber: fs pulse yb-fiber oscillator/amplifier system

- **Polarization is controlled by a built in PolaRITE III polarization controller**
- **Control voltages of the PolCont are set by a computer through an RS232 interface**
- **Pump powers of the diodes are set by a built in microcontroller unit**

Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)

FemtoCARS

The concept

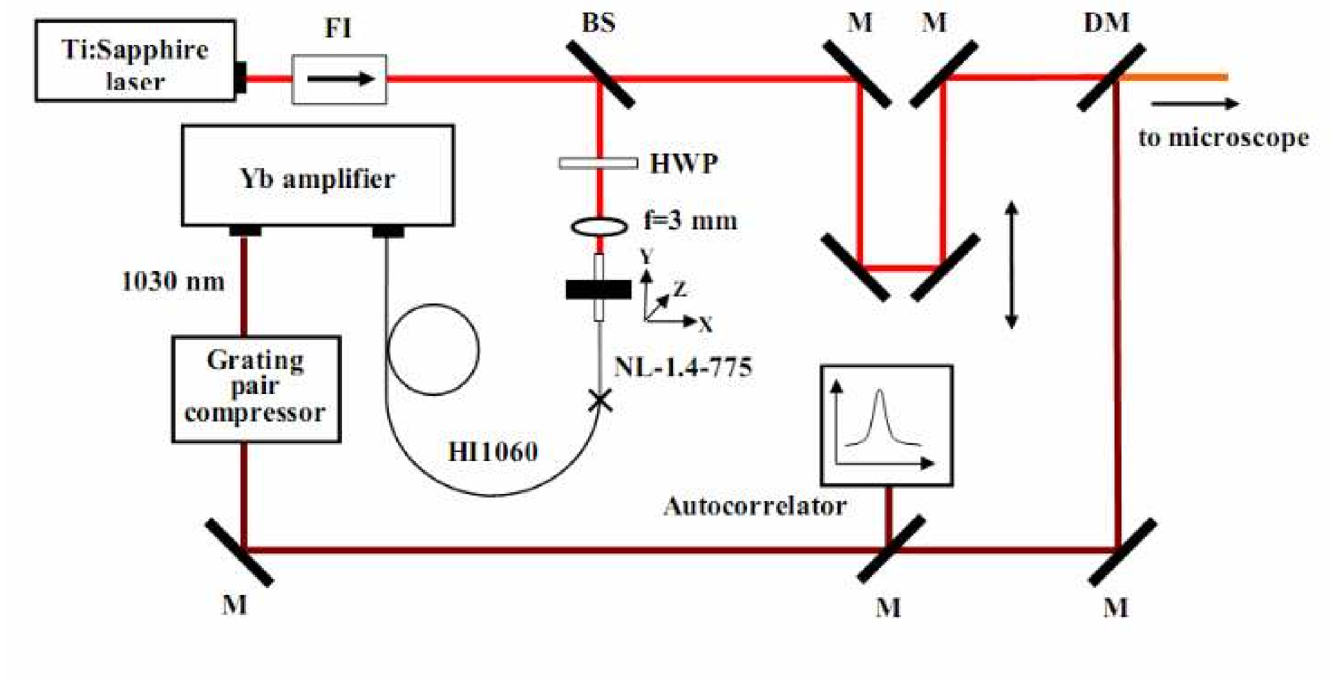


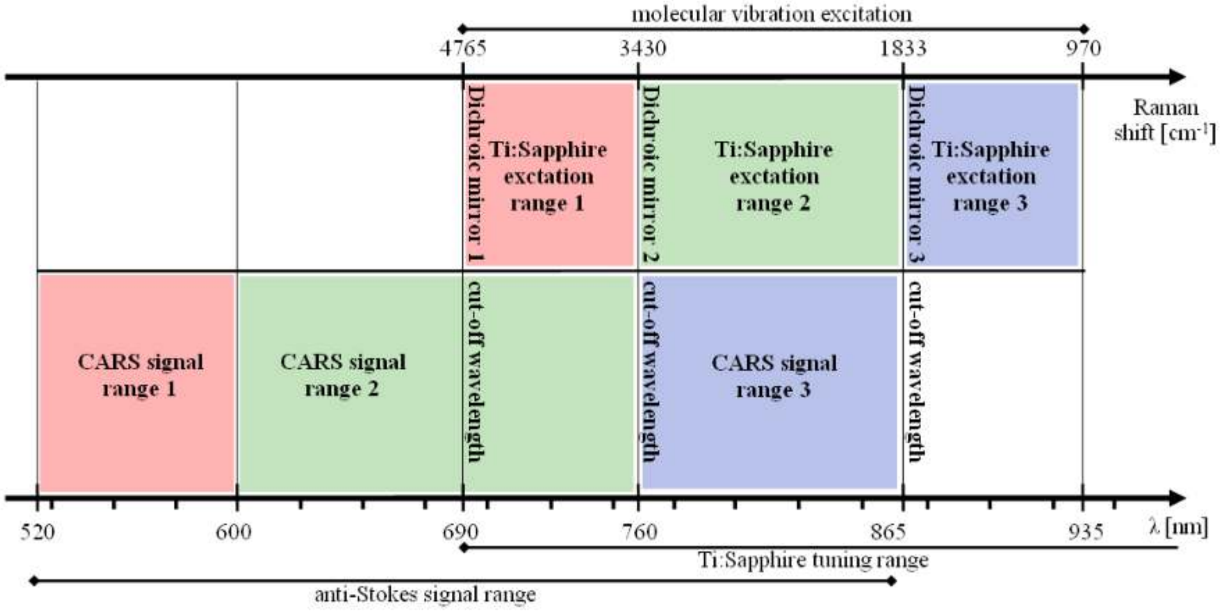
Fig. 1 Setup of the CARS extension unit

Kolonics A, Csáti D, Antal P, Szipőcs R; A simple, cost efficient fiber amplifier wavelength extension unit for broadly tunable, femtosecond pulse Ti-sapphire lasers for CARS microscopy; In: Proc. BIOMED Biomedical Optics and Digital Holography and Three Dimensional Imaging (Miami, Florida, United States, April 28-May 2 2012); OSA Technical Digest Series; BSu3A.28 /1-3 (2012)

Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)

FemtoCARS

The concept



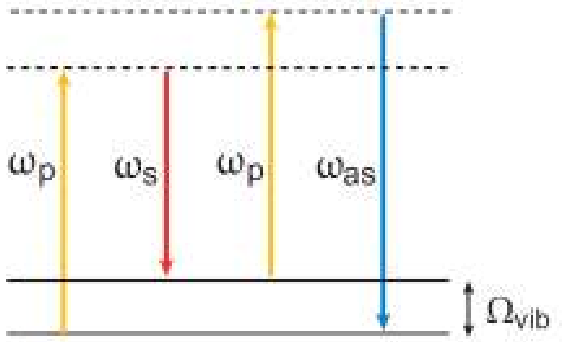
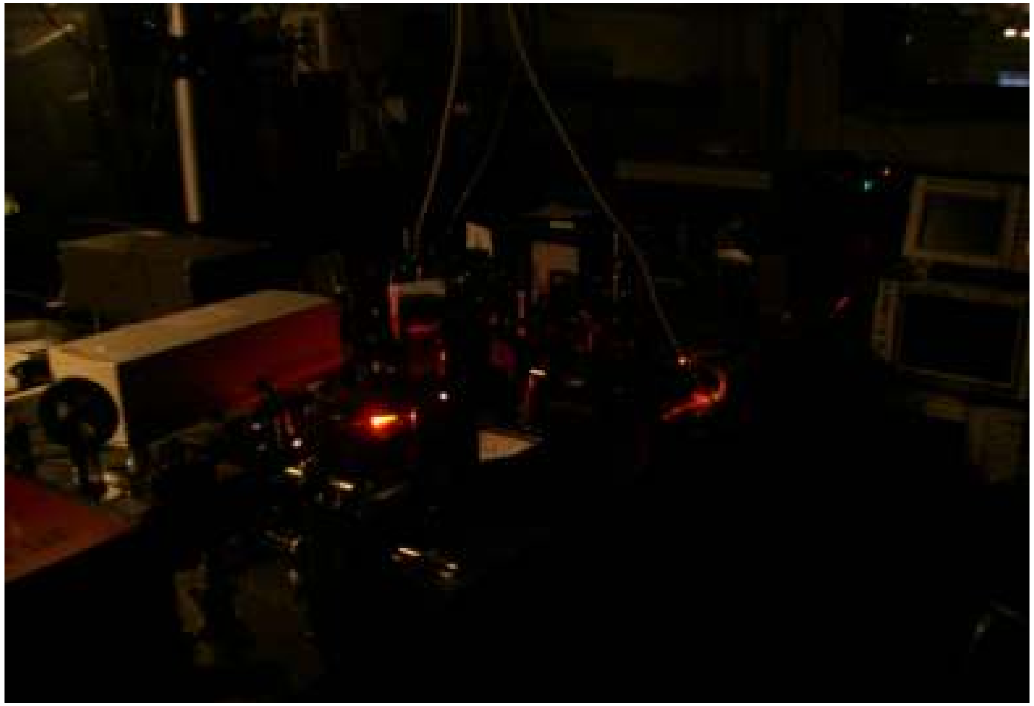


Fig. 1 The energy diagram of the CARS process: ω_p – the frequency of Ti-sapphire laser (pump), ω_S – the frequency of Yb-amplifier (Stokes), ω_{as} – the frequency of light generated during the CARS process, Ω_{vib} – vibration frequency of the investigated molecule

Kolonics A, Csáti D, Antal P, Szipőcs R; A simple, cost efficient fiber amplifier wavelength extension unit for broadly tunable, femtosecond pulse Ti-sapphire lasers for CARS microscopy; In: Proc. BIOMED Biomedical Optics and Digital Holography and Three Dimensional Imaging (Miami, Florida, United States, April 28-May 2 2012); OSA Technical Digest Series; BSu3A.28 /1-3 (2012)

FemtoCARS

Prototype at Wigner RCP



Kolonics A, Csáti D, Antal P, Szipőcs R; A simple, cost efficient fiber amplifier wavelength extension unit for broadly tunable, femtosecond pulse Ti-sapphire lasers for CARS microscopy; In: Proc. BIOMED Biomedical Optics and Digital Holography and Three Dimensional Imaging (Miami, Florida, United States, April 28-May 2 2012); OSA Technical Digest Series; BSu3A.28 /1-3 (2012)

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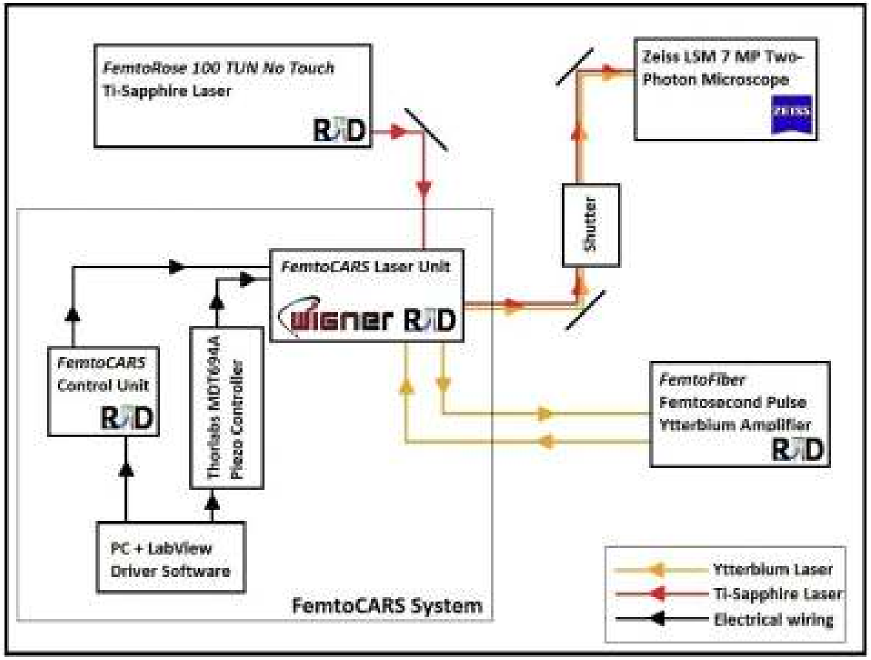
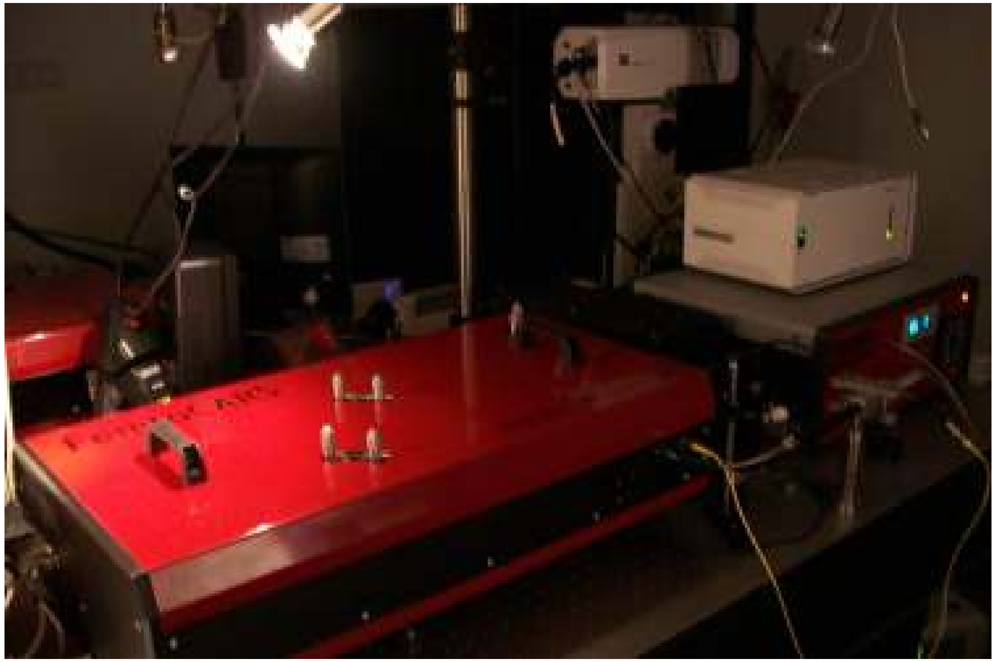
FemtoCARS

the

Label-free, 3D Microscopic Imaging System for Real-time in vivo Diagnostics





Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)

CONTROL

CARS SYSTEM INSTALLED AT UNIVERSITY OF SZEGED

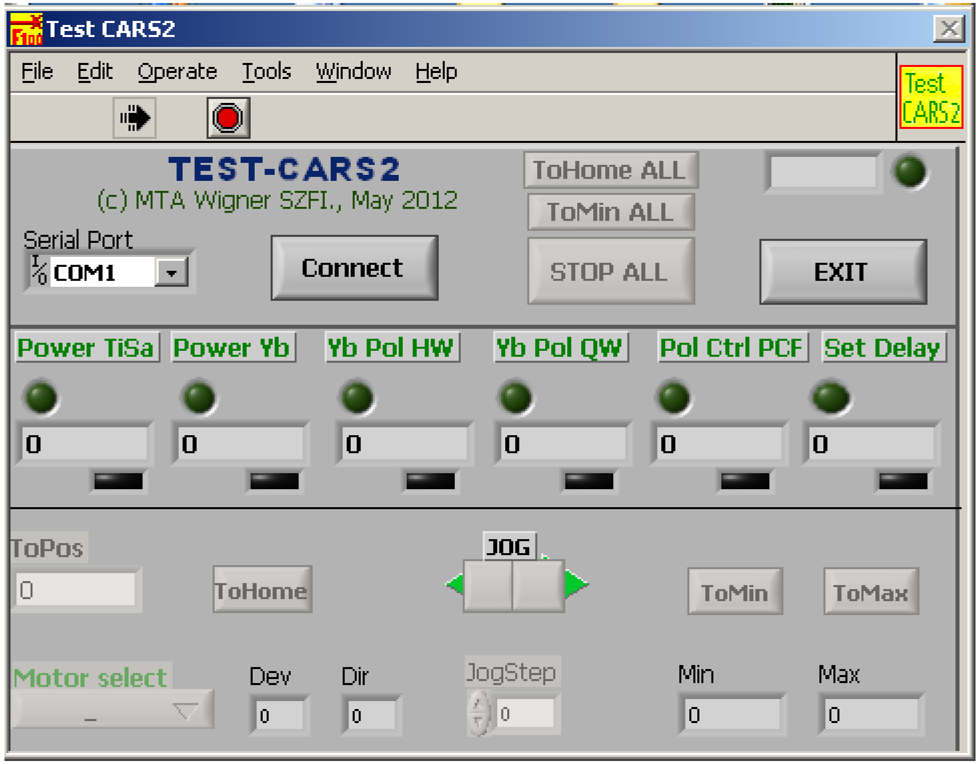
Related articles

CARS imaging system installed at the University of Szeged, Department of Neurology (Prof. Gábor Tamás lab), June 2014

Photo Gallery

CONTROL

Step motor drivers
LabView programs for control
Data colletion by DAQmX cards (NI)



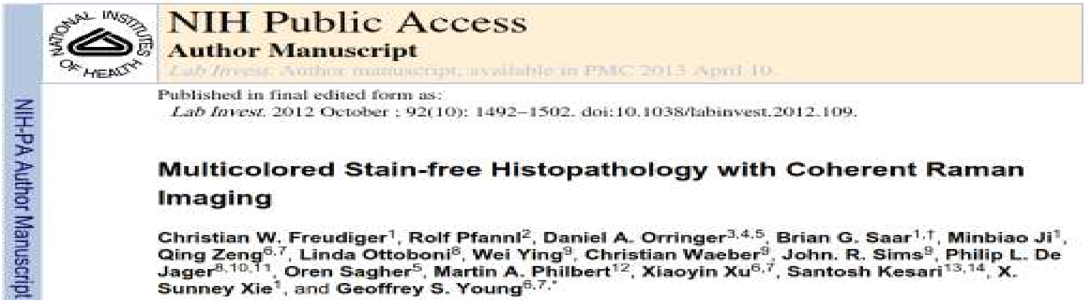
Test CARS2

TEST-CARS2

(c) MTA Wigner SZFI., May 2012

Serial Port: COM1

Research and development sponsored by TECH_09-A2-2009-0134 project (R&D Ultrafast Laserrs Ltd.)



Published in final edited form as:
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Multicolored Stain-free Histopathology with Coherent Raman Imaging

Christian W. Freudiger[1], Rolf Pfannl[2], Daniel A. Orringer[3,4,5], Brian G. Saar[1,†], Minbiao Ji[1], Qing Zeng[6,7], Linda Ottoboni[8], Wei Ying[9], Christian Waeber[9], John. R. Sims[9], Philip L. De Jager[8,10,11], Oren Sagher[5], Martin A. Philbert[12], Xiaoyin Xu[6,7], Santosh Kesari[13,14], X. Sunney Xie[1], and Geoffrey S. Young[6,7,*]

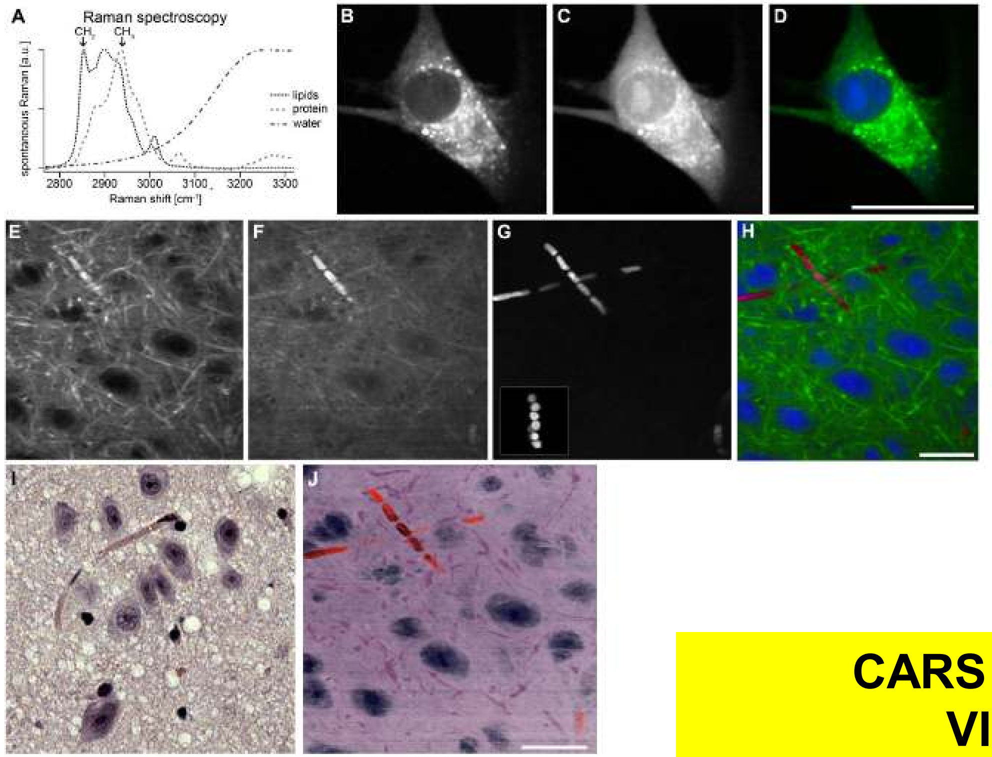


Figure 1.

Stain-free histologic imaging with multi-color CRI. (**A**) Vibrational spectra of the major constituents of tissue: lipids, protein and water. Arrows indicate Raman shifts at which imaging is performed. (**B-D**) SRS images of a live C2C12 mammalian cell acquired at the CH_2-stretching vibration at 2845cm^{-1} (B) and CH_3-stretching vibration at 2940cm^{-1} (C). Multicolor image (D) generated from images (B) and (C) with the green channel (CH_2 image) showing the cell-body and the blue channel (thresholded CH_3-CH_2 difference image) highlighting the nuclear morphology including a bright nucleolus. (**E-H**) SRS images of fresh *ex vivo* brain tissue acquired at CH_2-stretching vibration at 2845cm^{-1} (E), CH_3-stretching vibration at 2940cm^{-1} (F), and vibrationally off-resonant showing TPA of hemoglobin at a sum frequency of 23,700 cm^{-1} (G). Multicolor image (H) generated from images (E-G) with the green channel (CH_2 image) highlighting cytoplasm and myelin sheaths, blue channel (thresholded CH_3-CH_2 difference image) showing the nuclear morphology, and the red channel (hemoglobin image) highlighting red blood cells. (**I**) H&E-stained micrograph from the same region in the brain. (**J**) Same multicolor image as (H) with a different pseudo-color scheme, chosen to mimic the appearance of an H&E-stained micrograph, illustrates the similar image content and appearance of stain-free images and H&E stained sections. Scale bar, 25 μm.

CARS IN VIVO PATOLÓGIAI VIZSGÁLATOKHOZ

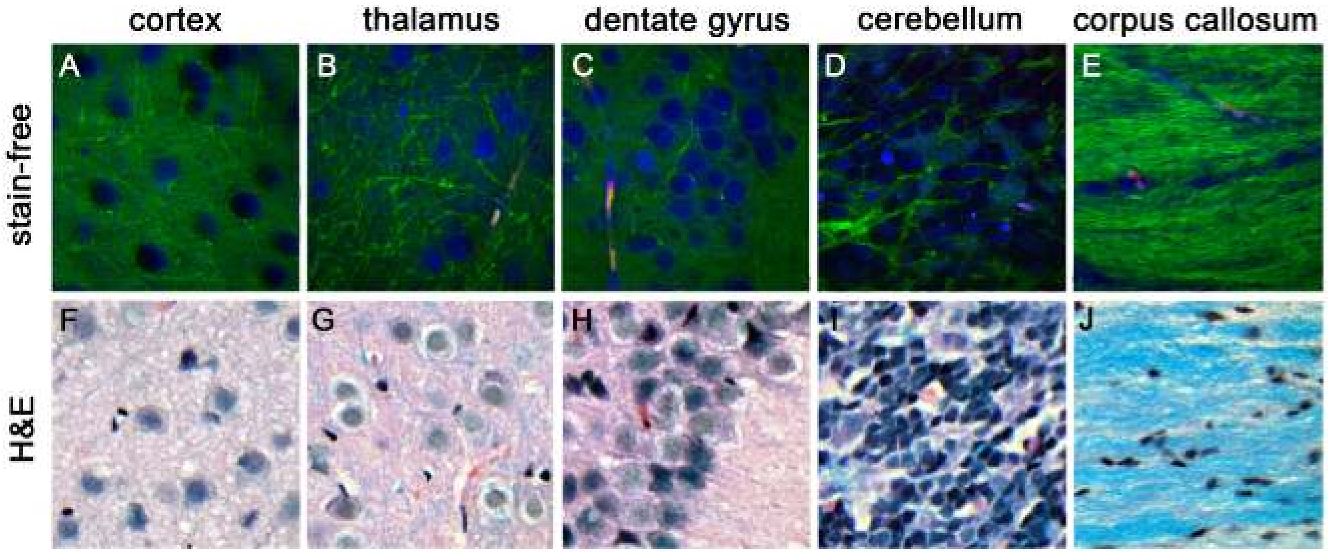


Figure 3.
Multicolor stain-free images of various brain regions in a wild-type mouse in comparison with paraffin-embeded, H&E and Luxol-stained sections.(green: CH_2 image; blue: CH_3-CH_2 difference image; red: hemoglobin image) of (**A**) cortex, (**B**) thalamus, (**C**) dentate gyrus, (**D**) cerebellum, and (**E**) corpus callosum. (**F**-**J**) show H&E/luxol stained section of corresponding regions.

FemtoCARS

the
Label-free, 3D Microscopic Imaging System for Real-time in vivo Diagnostics

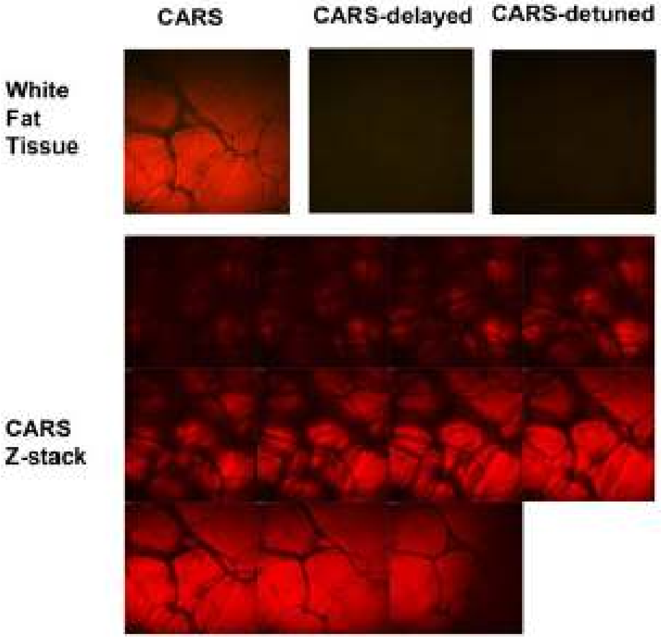
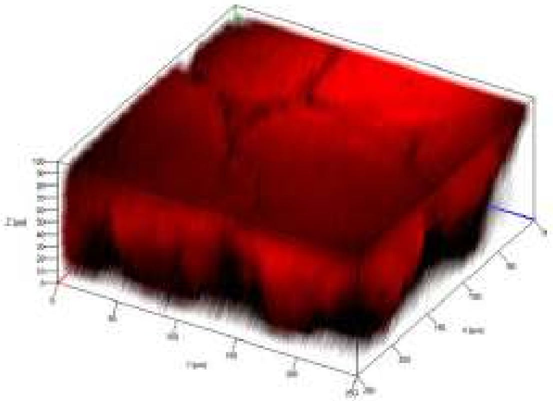


Fig. 3 CARS-images of murine white adipose tissue.



Kolonics A, Csáti D, Antal P, Szipőcs R; A simple, cost efficient fiber amplifier wavelength extension unit for broadly tunable, femtosecond pulse Ti-sapphire lasers for CARS microscopy; In: Proc. BIOMED Biomedical Optics and Digital Holography and Three Dimensional Imaging (Miami, Florida, United States, April 28-May 2 2012); OSA Technical Digest Series; BSu3A.28 /1-3 (2012)

FemtoCARS
the
Label-free, 3D Microscopic Imaging System for Real-time in vivo Diagnostics

Dermis

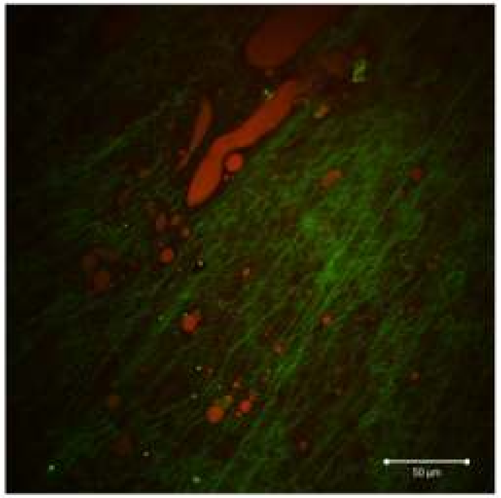


Photo: Kolonics/Szipőcs

Epidermis

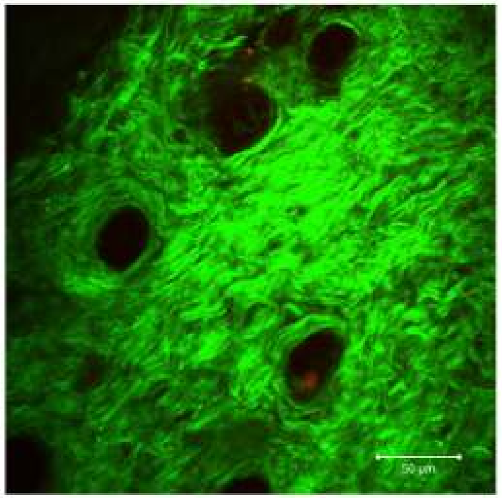
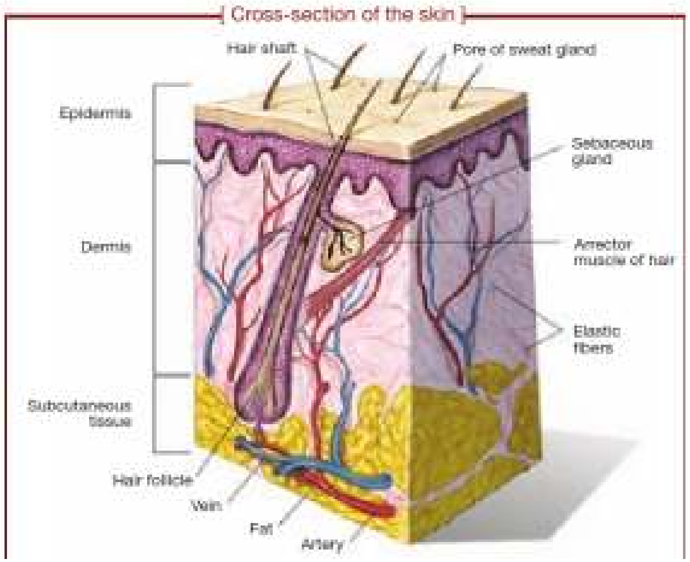


Photo: Kolonics/Szipőcs



red: CARS signal from lipids, green: SHG signal of collagene

FemtoCARS
the
Label-free, 3D Microscopic Imaging System for Neurology

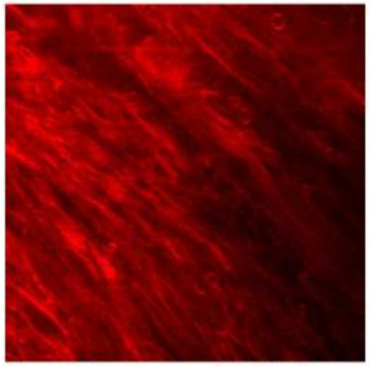
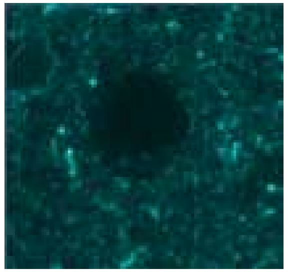


Figure 1. CARS image of myelin fibers in the white matter of rat. In vivo preparation.

In 2012, a novel, cost efficient CARS imaging setup was developed at Wigner RCP of HAS (Csati, 2012), which was used for label-free, 3D microscopic imaging of different biological samples, such as white adipose tissue (Kolonics, 2012). A commercial version of the prototype CARS system at Wigner RCP has been constructed and built for the University of Szeged (USZ) by the end of 2012 by the R&D Ultrafast Laser Ltd in collaboration with Carl Zeiss Jena. The CARS imaging system comprises a femtosecond pulse, tunable Ti:sapphire laser (R&D), an inherently synchronized two-stage Yb-fiber amplifier unit (R&D), a CARS Unit (R&D) and a CARS-upgraded version (Wigner) of Axio Examiner LSM 7 MP microscope (Carl Zeiss). Using this commercial setup, researchers at USZ (Molnár G) and Wigner RCP (Szipőcs R) have demonstrated that this novel CARS-imaging setup allows for label free imaging of the brain (Figure 1.). For instance, tuning their CARS setup to CH_2 vibration of myelin lipids, they could record high quality 3D CARS images of the myelin. Since myelin loss and axonal degeneration are the pathological hallmarks of several inherited and acquired neurological disorders, a method that allows simultaneous visualization of the two inter-related processes in live tissues may have great research utility. Such method had not been available prior to the introduction of the CARS system.

HUNGARIAN BRAIN RESEARCH PROGRAM
NEMZETI AGYKUTATÁSI PROGRAM



3D mikroszkópia már létező klinikai alkalmazásai

The confocal microscope illuminates a portion of skin with the point source of light and detects the reflected light through a pinhole.

Lucid's non-invasive VivaScope confocal microscopes provide cellular resolution images to help identify various skin conditions.

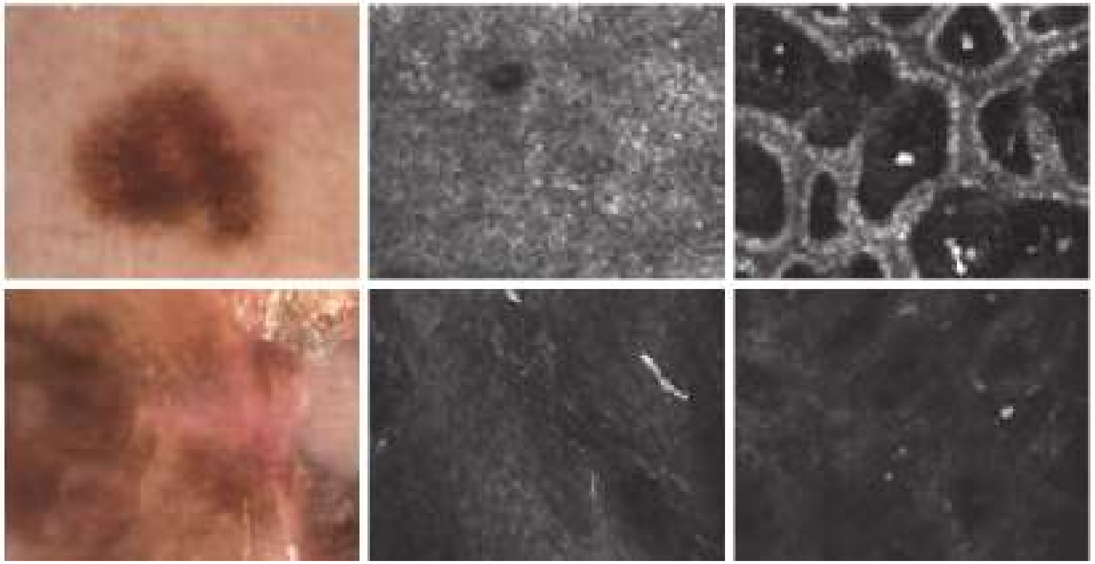
OPN November 2007 |

Miért előnyös az in vivo 3D mikroszkópia?

☺ **Tumor határának pontos meghatározásának lehetősége**

☺ **Nem kell várni a patológiai vizsgálatok eredményére!**

Given that this imaging form lets physicians look into tissue *in vivo* without any of the processing that is done in the pathology lab, confocal imaging may well reveal new skin features that cannot be directly correlated to the pathology.

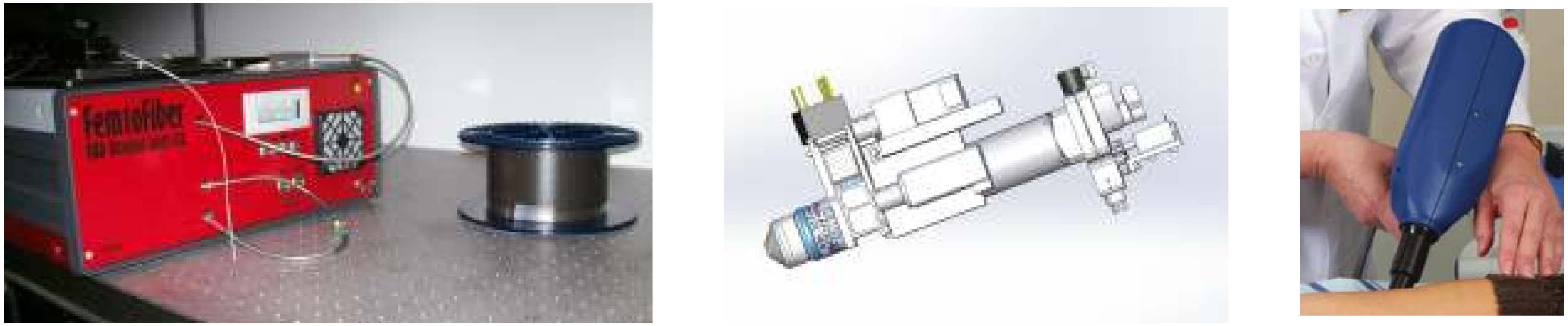


(Top) A benign mole viewed from (left) the skin's surface at visible wavelengths, (center) at a depth of 10 μm and (right) at 161 μm with infrared confocal microscopy. (Bottom) Malignant melanoma at (left) surface level in visible light, (center) at a depth of 35 μm and (right) at 95 μm with confocal microscopy.

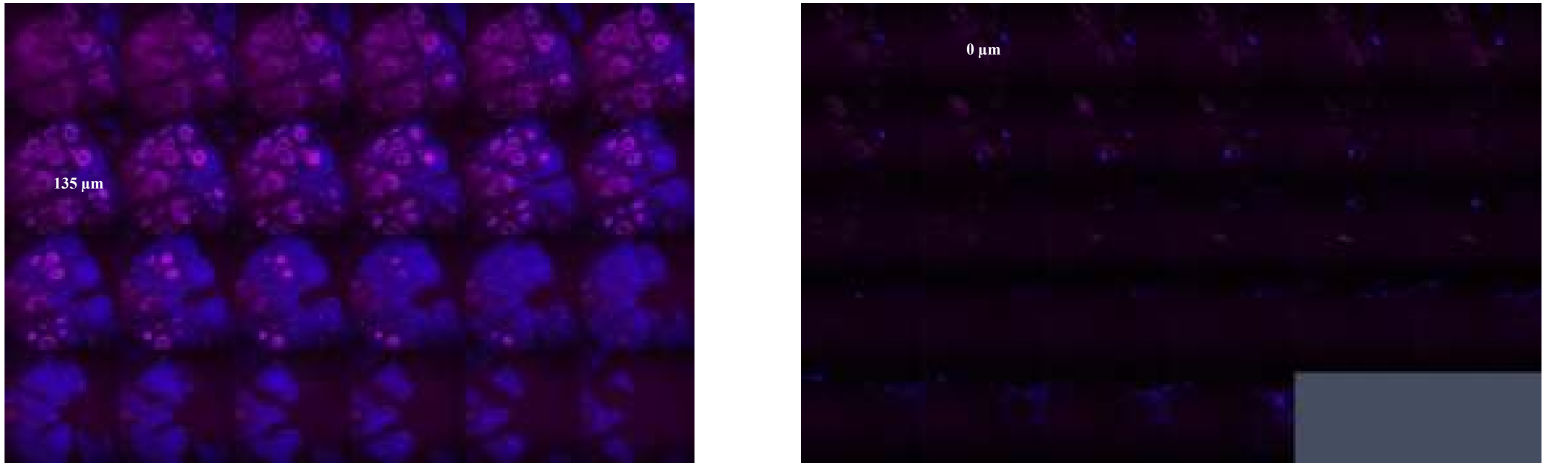
Semmelweis Egyetem
Bőr-, Nemikórtani
és Bőronkológiai Klinika

Basaliomák in vivo vizsgálata nemlineáris mikroszkópia módszerekkel

Wigner
Szipőcs Group



FemtoFiber + scanning head for confocal/2PF imaging = FiberScope



31 éves nőbeteg ép terület/tumor terület z-stack sorozat felvétel (AF+SHG)

Research and development sponsored by TECH_09-A2-2009-0134 project (Wigner RCP, R&D Ultrafast Laserrs Ltd.)

Természetes fluorofórok a bőrben: kollagén, elasztin, keratin

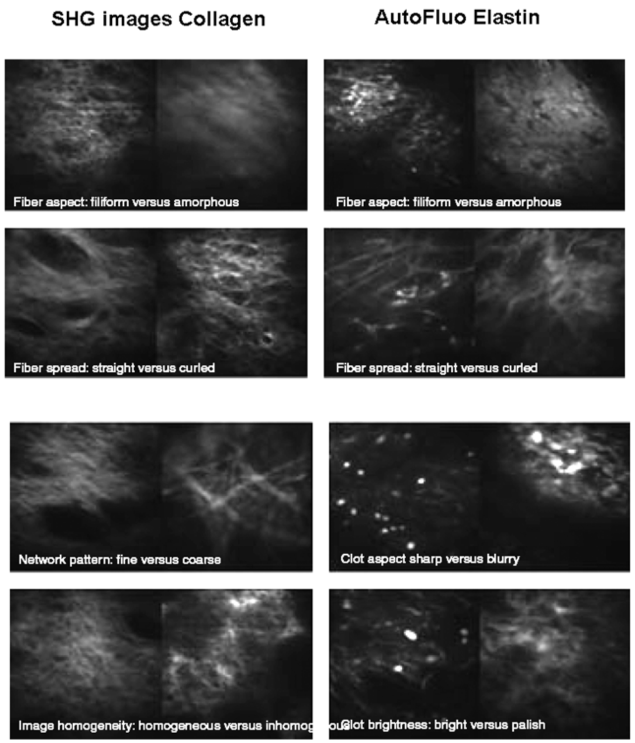
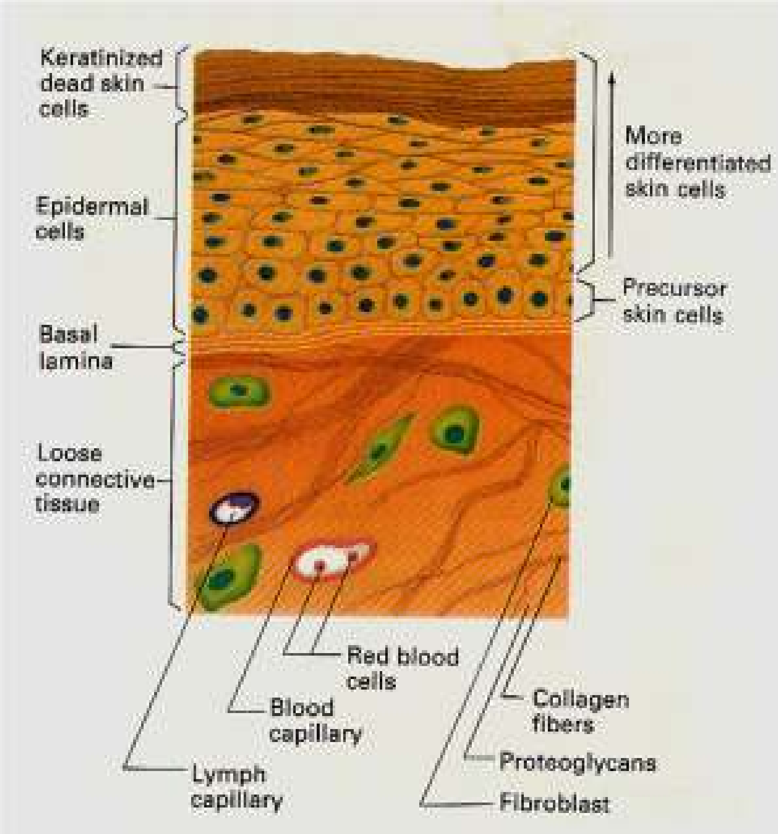


Figure 1. Optical slices obtained by multiphoton laser tomography of the superficial dermis depicting the category characteristics. Left side: second harmonics generation images depicting dermal collagen. Right side: autofluorescence images depicting dermal elastin. Edge length is about 0.2 mm.



Hans Georg Breunig, Hauke Studier and Karsten König, Opt. Exp. 18, 7857 (2010)

Természetes fluorofórok a bőrben: kollagén, keratin, NADH, melanin

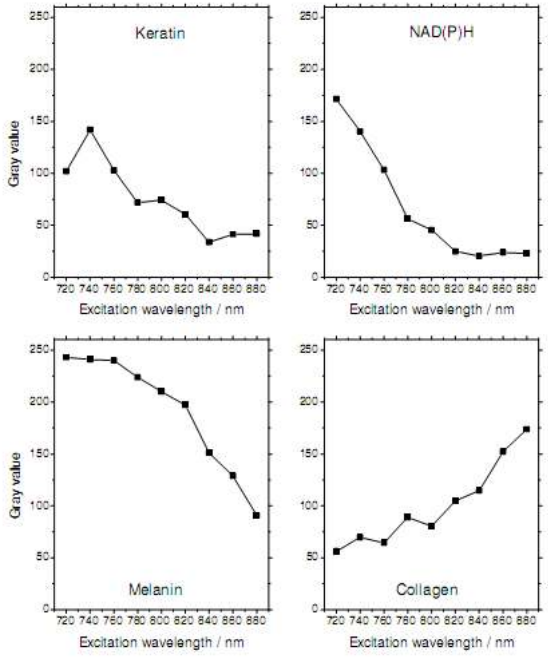
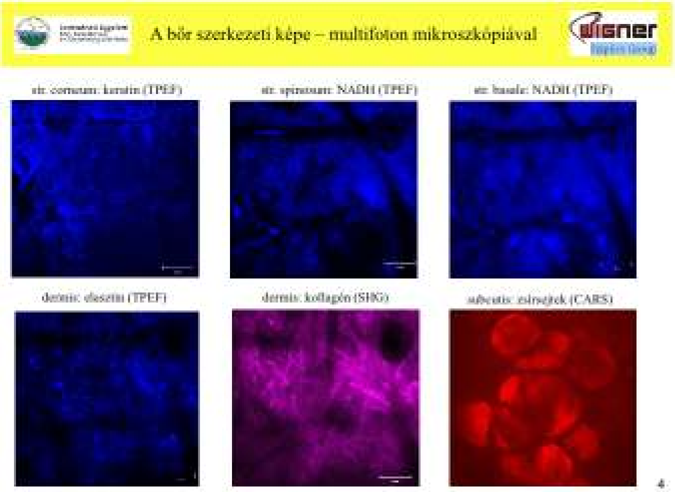


Fig. 8. Signal intensities of main fluorophores of human skin in dependence of excitation wavelength derived from Fig. 3 - Fig. 6.

Hangolható (femtoszekundumos) lézer kell!

Hans Georg Breunig, Hauke Studier and Karsten König, Opt. Exp. 18, 7857 (2010)

Mit, hogyan mérünk in vivo a bőrgyógyászatban?
(a lézerekkel és a leképező optikákkal kapcsolatos elvárások)



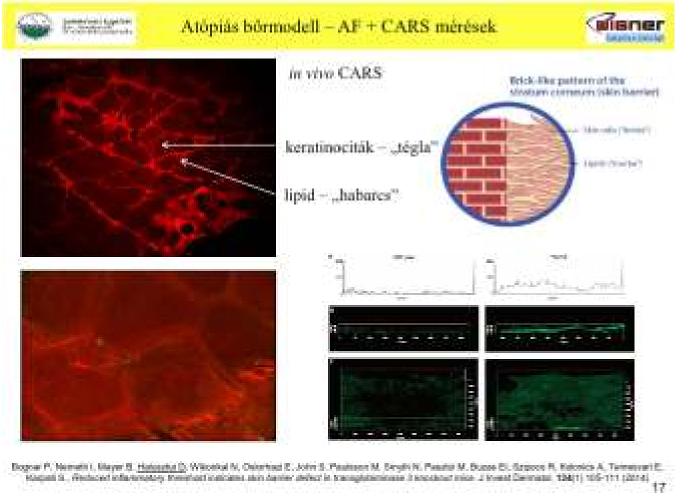
A bőr szerkezeti képe – multifoton mikroszkópiával

4

Biztonságtechnikai vizsgálatok

- **Károsító hatások**: hő-, mechanikai és fotokémiai
- Fotokémiai károsító hatások detektálása intracell. kromoforok két foton excitációja következtében alakul ki, **sejtes rendszerekben ez a károsodás teljesen hasonló az UVB besugárzás által okozottakkal**
- **Cyclobutane pyrimidin dimerek**: kovalens keresztkötések a DNS azonos láncán lévő szomszédos pirimidin bázisai között - NEB rendszer javítja – elégtelen javítás esetén – mutáció

5



Atópiás bőrmodell – AF + CARS mérések

Bognar P, Nemeth I, Mayer B, Haluszka D, Wikonkal N, Ostorhazi E, John S, Paulsson M, Smyth N, Pasztoi M, Buzas EI, Szipocs R, Kolonics A, Temesvari E, Kárpáti S., *Reduced inflammatory threshold indicates skin barrier defect in transglutaminase 3 knockout mice.* J Invest Dermatol. 134(1):105-111 (2014)

17

Basaliomák vizsgálata

- A hám bazális sejtrétegéből kiinduló rosszindulatú daganat, de áttétet nem képez
- Általában napfénynek kitett bőrfelületen alakul ki: arc, fül, nyak, vállak
- Több formája létezik
- Kezelés: sebészi excisió, 4-5mm biztonsági zónával
- Ennek ellenére gyakran recidivál
- A lézeres képalkotás megoldás lehet a pontos metszési sík meghatározásánál
- **Kollagén,** mint marker
- Ex vivo minták, műtét után

13

Semmelweis Egyetem
Bőr-, Nemikórtani
és Bőronkológiai Klinika

Basaliomák vizsgálata nemlineáris mikroszkópia módszerekkel

Wigner
Szipőcs Group

*Skin Research and Technology 2013; **19**: e297–e304*
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doi: 10.1111/j.1600-0846.2012.00643.x

Skin Research and Technology

Diagnosis of BCC by multiphoton laser tomography

Stefania Seidenari[1], Federica Arginelli[1], Sara Bassoli[1], Jennifer Cautela[1], Anna Maria Cesinaro[2], Mario Guanti[1], Davide Guardoli[1], Cristina Magnoni[1], Marco Manfredini[1], Giovanni Ponti[1] and Karsten König[3,4]

[1]Department of Dermatology, University of Modena and Reggio Emilia, Modena, Italy,
[2]Department of Pathology, University of Modena and Reggio Emilia, Modena, Italy,
[3]Department of Biophotonics and Lasertechnology, Saarland University, Saarbrücken, Germany and [4]JenLab GmbH, Schillerstrasse 1, 0745, Jena, Germany

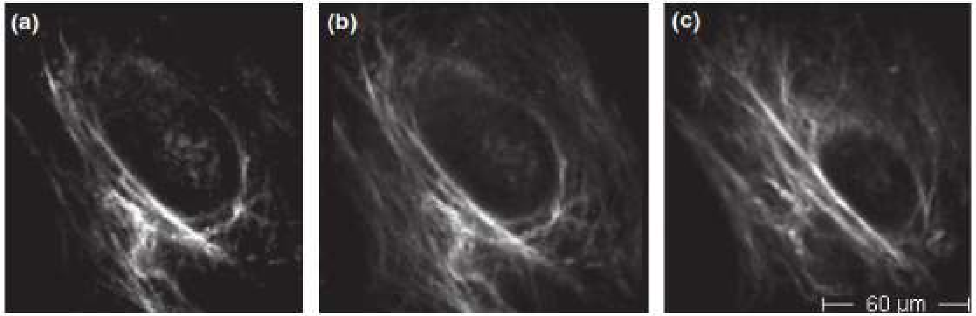
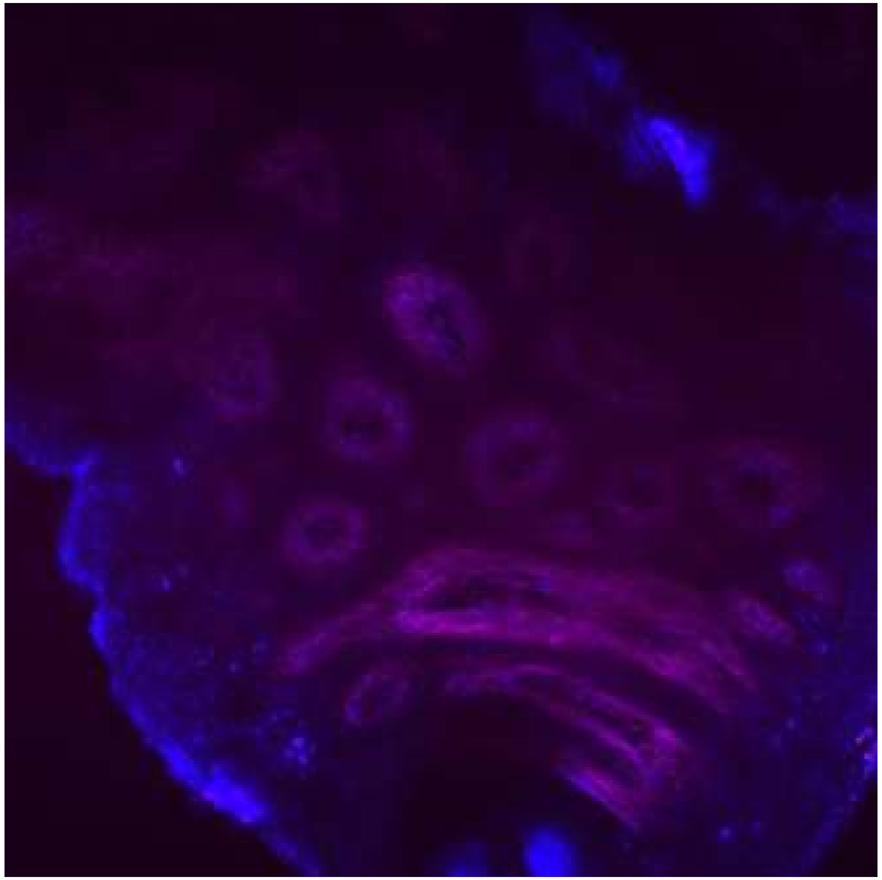


Fig. 4. Basal cell carcinoma. (a) 100 µm depth, excitation wavelength 800 nm. Shifting the wavelength to 800 nm, basaloid cells become less visible; employing an excitation wavelength of 820 nm basaloid cells disappear and it is possible to observe empty spaces surrounded by collagen fibres (phantom island); (b) 100 µm depth; (c) 120 µm depth.

Basalioma vizsgálata – 3D FiberScope fejlesztése



Kollagén szerkezet – SHG
Sejtek - autofluoreszcencia

- Lézer hullámhossza
- Színszűrők kiválasztása

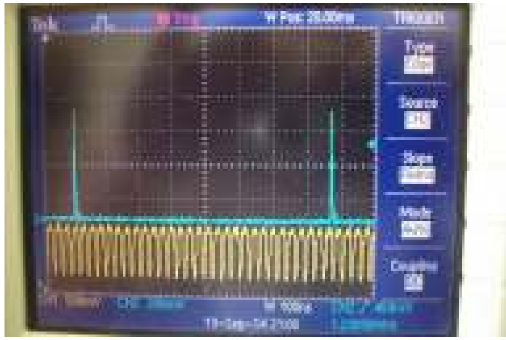
Szállézer specifikálása
Optikai szál specifikálása

Biztonságtechnikai vizsgálatok

Research and development sponsored by TECH_09-A2-2009-0134 project (Semmelweis University, Wigner RCP, R&D Ultrafast Laserrs Ltd.)

2P mikroszkópiás mérések, BCC vizsgálata

FiberScope, a kézben tartott nemlineáris mikroszkóp



Lézeres fényforrás: 2-36 MHz-es ismétlési frekveniájú, impulzusüzemű Yb-szállézer, erősítő rendszer

Leképező optika: kisméretű pásztászó mikroszkóp

Mind a lézerforrás, mind a mikroszkóp optimalizált az adott orvosi diagnosztikai feladathoz: alacsony ár!

Biztonságtechnikai vizsgálatok

Research and development sponsored by TECH_09-A2-2009-0134 project (Wigner RCP, R&D Ultrafast Laserrs Ltd.)

2P mikroszkópiás mérések, BCC vizsgálata

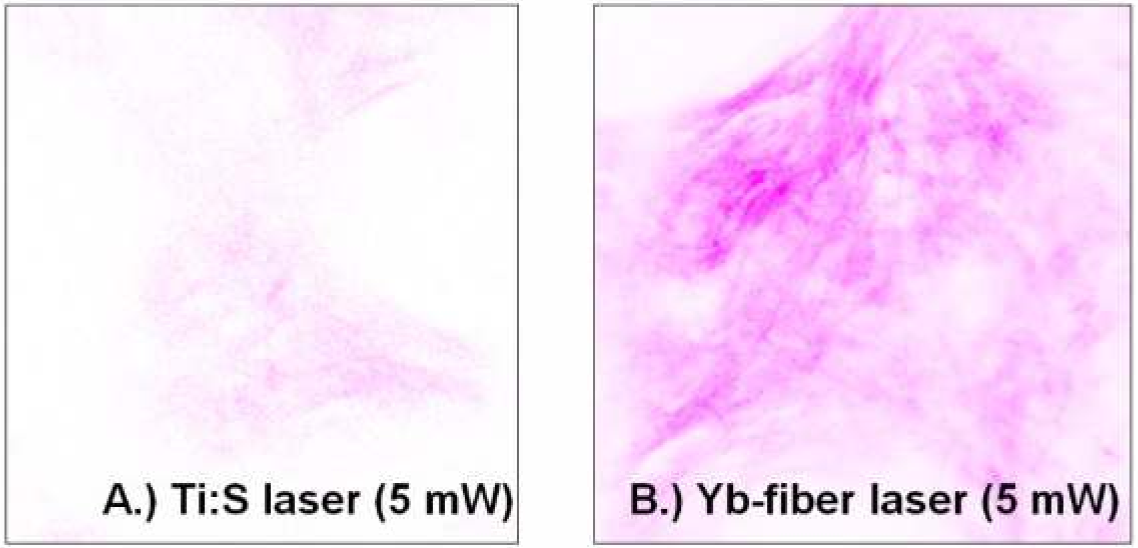


Figure 1. *Comparison of SHG imaging performance of different mode-locked lasers having the same average power of 5 mW (on the sample) for nonlinear microscopy. Ex-vivo murine skin sample, imaging depth: z = 30 µm, same microscope settings. Collagen distribution measured by A) an industry standard, 80 MHz Ti:sapphire laser, and by B) our newly developed Yb-fiber oscillator and amplifier system (with a variable repetition rate).*

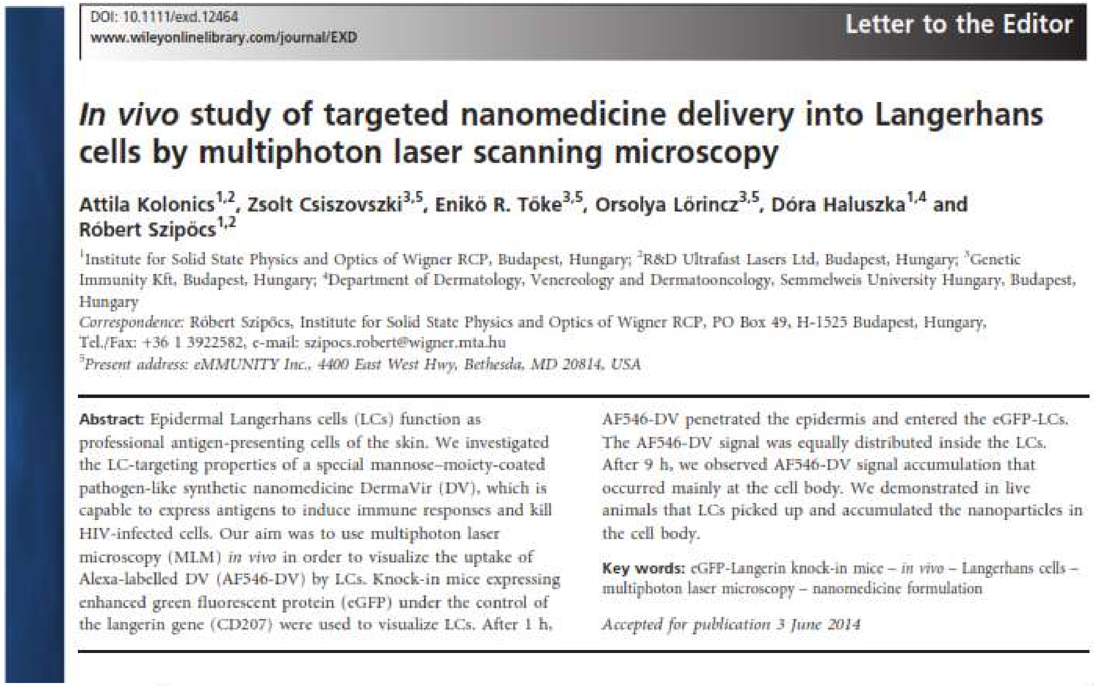
Research and development sponsored by TECH_09-A2-2009-0134 project (Semmelweis University, Wigner RCP, R&D Ultrafast Laserrs Ltd.)

2P mikroszkópiás mérések
Gyógyszeripai alkalmazások

Experimental Dermatology

The official journal of Arbeitsgemeinschaft Dermatologische Forschung,

Editors:
Thomas A. Luger, Münster, Germany
Ralf Paus, Manchester, UK & Münster, Germany



DOI: 10.1111/exd.12464
www.wileyonlinelibrary.com/journal/EXD

Letter to the Editor

In vivo study of targeted nanomedicine delivery into Langerhans cells by multiphoton laser scanning microscopy

Attila Kolonics[1,2], Zsolt Csiszovszki[3,5], Enikö R. Tőke[3,5], Orsolya Lőrincz[3,5], Dóra Haluszka[1,4] and Róbert Szipőcs[1,2]

[1]Institute for Solid State Physics and Optics of Wigner RCP, Budapest, Hungary; [2]R&D Ultrafast Lasers Ltd, Budapest, Hungary; [3]Genetic Immunity Kft, Budapest, Hungary; [4]Department of Dermatology, Venereology and Dermatooncology, Semmelweis University Hungary, Budapest, Hungary

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Abstract: Epidermal Langerhans cells (LCs) function as professional antigen-presenting cells of the skin. We investigated the LC-targeting properties of a special mannose–moiety-coated pathogen-like synthetic nanomedicine DermaVir (DV), which is capable to express antigens to induce immune responses and kill HIV-infected cells. Our aim was to use multiphoton laser microscopy (MLM) *in vivo* in order to visualize the uptake of Alexa-labelled DV (AF546-DV) by LCs. Knock-in mice expressing enhanced green fluorescent protein (eGFP) under the control of the langerin gene (CD207) were used to visualize LCs. After 1 h, AF546-DV penetrated the epidermis and entered the eGFP-LCs. The AF546-DV signal was equally distributed inside the LCs. After 9 h, we observed AF546-DV signal accumulation that occurred mainly at the cell body. We demonstrated in live animals that LCs picked up and accumulated the nanoparticles in the cell body.

Key words: eGFP-Langerin knock-in mice – *in vivo* – Langerhans cells – multiphoton laser microscopy – nanomedicine formulation

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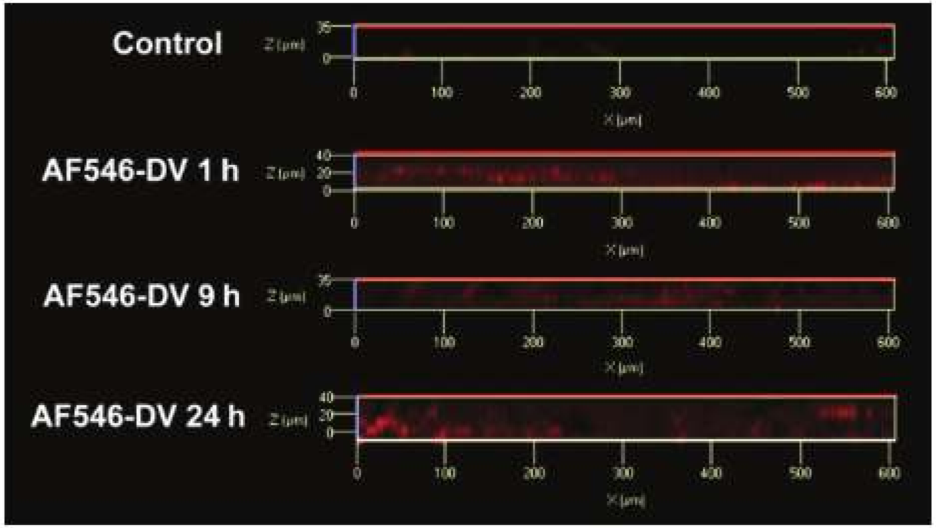

Figure 1. Penetration kinetics of AF546-DV through the stratum corneum in enhanced green fluorescent protein (eGFP)-Langerin knock-in mouse ear *in vivo*. *xz*-Multitracking sections were composed from a stack of *xy*-optical sections with 5 μm distances between the sections. The sections were recorded from the stratum corneum ($Z = 0$ μm) to the epidermis ($Z = 35$–40 μm). These representations reveal the penetration profiles of AF546-DV into eGFP-Langerin knock-in mouse skin reaching an average of 20 μm penetration depth underneath the honeycomb-shaped corneocyte layer after 1 h of topical treatment. AF546-DV diffused in the whole depth of the skin after 9 or 24 h despite of the fact that a part of the AF546-DV formula dried on the stratum corneum. Control: intact skin without AF546-DV.

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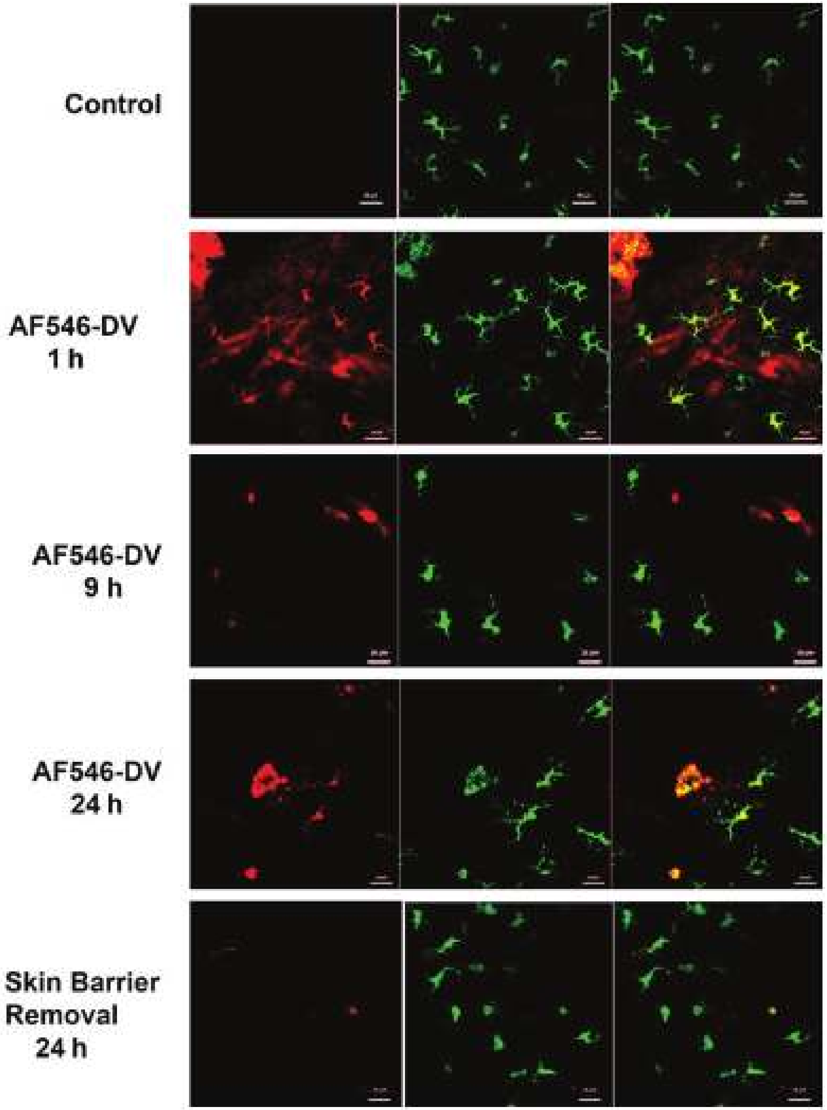

Figure 2. Kinetics of AF546-DV uptake by Langerhans cells (LCs) in eGFP-Langerin knock-in mouse ear *in vivo*. Nearly all LCs had incorporated AF546-DV after 1 h of topical treatment: strong colocalization was detected in both channels [NDD 2 – green/eGFP (middle column) versus NDD 1 – red/AF546-DV (left column)] as presented on the merged pictures (right column). Images of red light emission also revealed that the nanoparticles were distributed homogenously in all parts of the LCs. After 9 h, the intensity of red light emission by AF546-DV decreased significantly and disappeared from the dendrites and concentrated around the nucleus. Intriguingly, after 24 h, the nuclear location as well as a weak signal of AF546 in the dendrites could still be observed. The removal of the stratum corneum resulted in the activation of the vast majority of the LCs characterized by a rounded potato-like shape. The scale bar represents 20 μm.

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