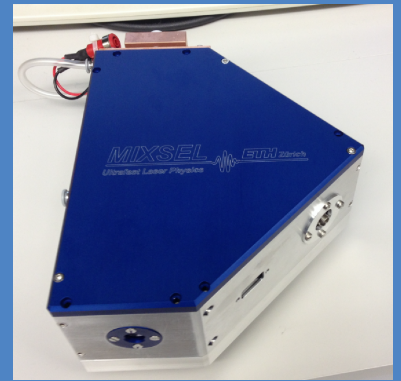




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MIXSEL II

NOVEL SEMICONDUCTOR DISK LASERS FOR BIOMEDICAL
AND METROLOGY APPLICATIONS



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What it's about...

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Context and project goals

Following on from Nano-Tera Phase I project MIXSEL, we want to exploit our scientific leadership and consolidate our research efforts for real application demonstrations. We will continue to improve the VECSEL and MIXSEL sources towards prototype demonstrators for end-user demonstration in biomedical imaging, compact efficient white light generation for general high brightness illumination and frequency metrology applications. End-user demonstration will take place with our newly added university and industrial partners.

The high potential in metrology will be investigated and exploited by the University of Neuchâtel, and two new partners, the Federal Office of Metrology (METAS) and the company ABB (financed by their own contribution). Biomedical imaging will be exploited together with the light microscopy and screening center (LMSC) at ETH Zurich and applications in high brightness illumination by Volpi AG. RUAG will be an end-user for applications in space missions. Industrial transfer of this technology is planned with the Swiss company TimeBandwidth Products AG (who previously secured IP for ultrafast optically pumped VECSELs and MIXSELs) and with Oclaro when larger scale production can be started.

Therefore the Phase II of the MIXSEL project will consolidate and continue with the most promising laser technology to achieve real application demonstrations. We will concentrate on optically pumped VECSELs and MIXSELs at a center wavelength of 950 nm to 980 nm where we achieved the best results. We will not focus on a specific wavelength demonstration because this can be done at a later stage. The wavelength range proposed here is typically used for bio-medical imaging and white light generation works even better at this shorter wavelength compared to 1.5 μm . During the initial MIXSEL project it also has become clear that electrically pumped VECSELs/MIXSELs will be limited in output power because of the design trade-offs between modelocking and power scaling. A key milestone demonstration of optically pumped MIXSELs and SESAM modelocked VECSELs is shorter femtosecond pulses in the range of 100 fs to 300 fs with more than 1 W average output power. We will develop prototype demonstrators for the target applications mentioned above.

How it differentiates from similar projects in the field

The project's SESAM-modelocked VECSEL and MIXSEL technology is world leading, still being the only group that has realized a MIXSEL. Furthermore it has been demonstrated that these semiconductor modelocked lasers have superior noise level performance compared to other semiconductor laser technologies. This, in combination with outstanding knowledge of frequency comb stabilization, should lead to the first fully stabilized frequency comb from an ultrafast semiconductor laser.

Quick summary of the project status and key results

The pulse duration of MIXSELS has been reduced to 253 fs in 235 mW of average output power at 3.35 GHz repetition rate.

A SESAM-modelocked VECSEL generated 128-fs pulses in 80 mW average output power at 1.8 GHz repetition rate. These are the shortest pulses achieved from a semiconductor disk lasers with >10 mW average power.

A novel dual-comb MIXSEL concept has been invented, generating two orthogonal modelocked laser beams with slightly different repetition rates from the same laser. Interesting for dual comb spectroscopy application (Swiss patent application filed).

First biomedical imaging experiments were performed using our SESAM-modelocked VECSELS generating pulses with a duration of 263 fs, a pulse repetition rate of 1.77 GHz and an average power of 360 mW (in collaboration with Prof. Helmchen from the University of Zurich).

Success stories

The team was able to reduce the pulse length of MIXSELS down to sub-300-fs and scaling the average output power to 310 mW.

The pulse length of SESAM modelocked VECSELS has been reduced down to 128 fs and 80 mW average output power. Direct supercontinuum generation without pulse compression should become possible with more average output power.

The team has been able to build and distribute three SESAM modelocked VECSEL prototypes. One older laser was used for the collaboration with the University of Zurich for two-photon microscopy. Two of the three new ones were transferred to the University of Neuchâtel and to METAS.

A new type of dual-comb MIXSEL concept was invented, generating two modelocked laser beams from the same laser resonator. The two modelocked laser beams have a slightly different repetition rate and have orthogonal polarizations which makes it possible to do dual-comb spectroscopy with this very compact laser, without the need to synchronize two different lasers.

First biomedical imaging experiments done using the SESAM modelocked VECSELS generating pulses with a duration of 263 fs, a pulse repetition rate of 1.77 GHz and an average power of 360 mW. For gigahertz pulse repetition rates (and therefore higher average power), samples with less absorption are needed to reduce parasitic heating degradation. On the other hand the high average photon flux and the wavelength flexibility of VECSELS/MIXSELS can then help to obtain better signal-to-noise with samples dominated by scattering losses.

The dual-comb MIXSEL technology has been filed for initial patent application.

To further explore the field of frequency combs, which are one promising application for the MIXSELS developed in this project, co-investigator Thomas Südmeyer together with PI Ursula Keller and industrial partner JDSU Ultrafast Lasers AG successfully launched the KTI research grant "Gigahertz optical frequency comb". This

grant started in April 2015 and uses solid-state lasers. The project targets a novel technology platform of ultrafast diode-pumped solid-state lasers with a repetition rate in the gigahertz range and their full stabilization for optical frequency combs that will benefit many present and emerging applications. A new class of oscillators will be produced for the R&D and biomedical markets and a complete self-referenced GHz frequency comb prototype will be developed to penetrate new markets in optical metrology.

Presence in the media

LaserFocusWorld, 04/07/2014 *MIXSEL: Ultrafast goes simple*

SemiconductorToday, 04/08/2014, *Improving electrically pumped external-cavity mode-locking*

Awards

Mario Mangold received the presentation award during the VECSEL conference at Photonics West 2014 in San Francisco.

Ursula Keller was awarded with the 2015 Charles H. Townes Award of OSA for her seminal contributions in the fields of octave-spanning lasers, frequency comb technology, and high repetition-rate ultrafast semiconductor disc lasers.

Main publications

M. Mangold, V. J. Wittwer, C. A. Zaugg, S. M. Link, M. Golling, B. W. Tilma, and U. Keller, Femtosecond pulses from a modelocked integrated external-cavity surface emitting laser (MIXSEL), *Opt. Express* 21(21), 24904-24911 (2013).

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Christian A. Zaugg, Alexander Klenner, Mario Mangold, Aline S. Mayer, Sandro M. Link, Florian Emaury, Matthias Golling, Emilio Gini, Clara J. Saraceno, Bauke W. Tilma, Ursula Keller, Gigahertz Self-referenceable Frequency Comb from a Semiconductor Disk Laser, *Opt. Express* 22(13), 16445-16455 (2014).

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S. M. Link, A. Klenner, M. Mangold, M. Golling, B. W. Tilma, U. Keller, Dual-comb modelocked lasers, *CLEO 2015*, San Jose, CA, USA, 10-15 May 2015.

D. Waldburger, M. Mangold, S. M. Link, M. Golling, E. Gini, B. W. Tilma, U. Keller, Sub-300-femtosecond Semiconductor Disk Lasers, *CLEO 2015*, San Jose, CA, USA, 10-15 May 2015.

“Modelocked semiconductor disk lasers:
a new standard for compact, ultrafast, high power lasers”