

A femtosecond MIXSEL

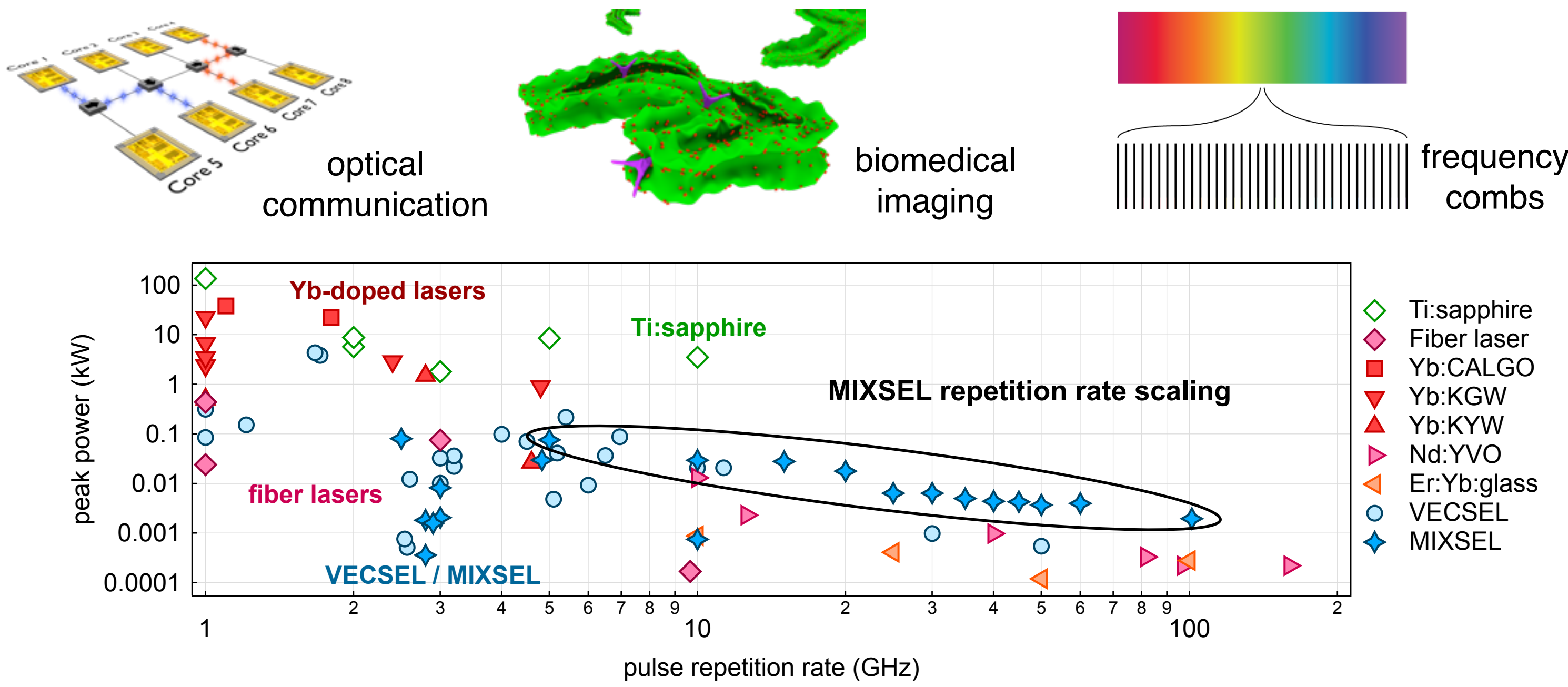
M. Mangold, C. A. Zaugg, S. M. Link, A. S. Mayer, M. Golling, B. W. Tilma, and U. Keller

ETH Zurich, Institute for Quantum Electronics, Ultrafast Laser Physics

ETH zürich

Motivation

Applications of ultrafast **semiconductor disk lasers (SDL)**



first Watt-level femtosecond VECSEL [1]

784-fs-pulses with >1 W output power in a 5.4 GHz V-cavity

first CEO-frequency detection of a SESAM-modelocked VECSEL [2]

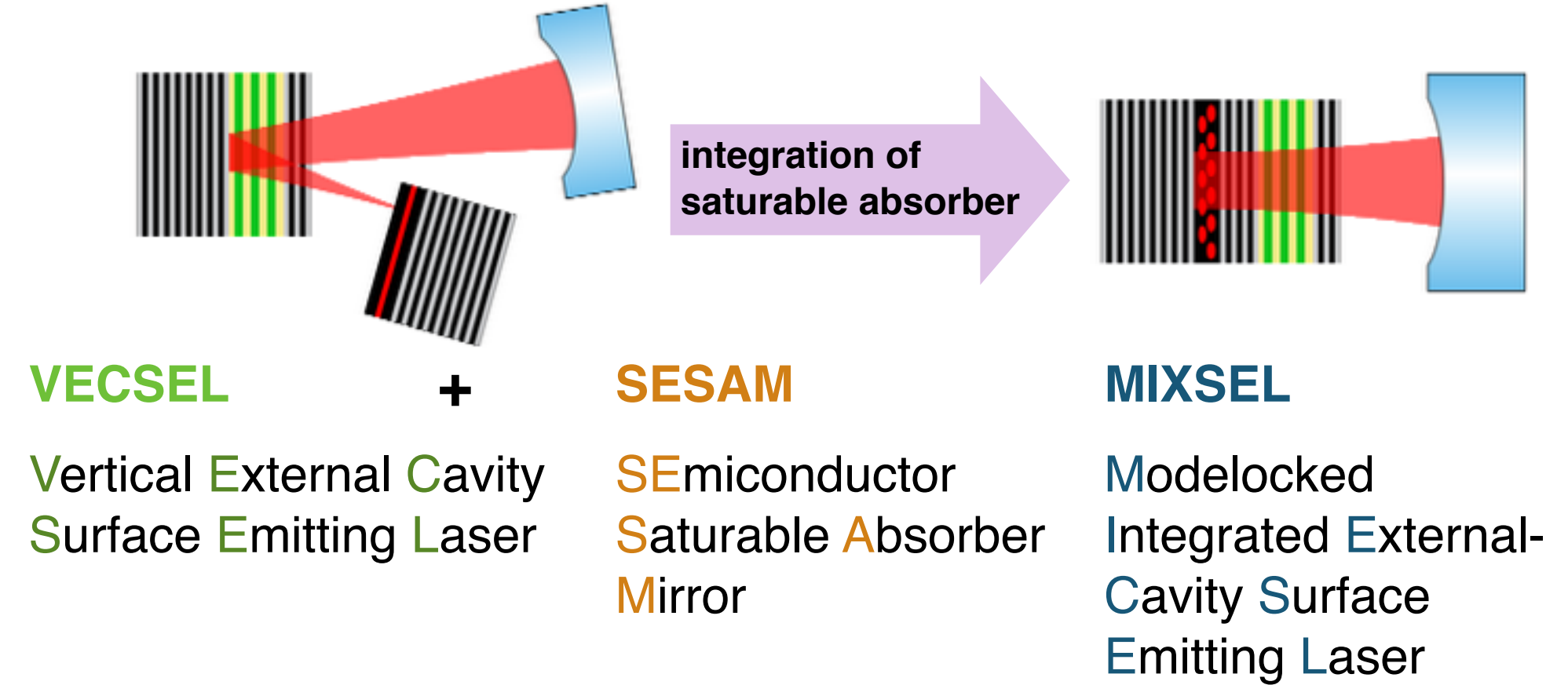
amplified and recompressed 238-fs pulses from a 100-mW VECSEL

[1] M. Hoffmann *et al.*, Optics Express (2011) vol. 19, 8108-8116

[2] C.A. Zaugg *et al.*, submitted to 6th EPS-QEOD Europhoton Conference

MIXSEL concept

- semiconductor based
- integrated saturable absorber
- power scalable
- potential for monolithic design
- low noise operation



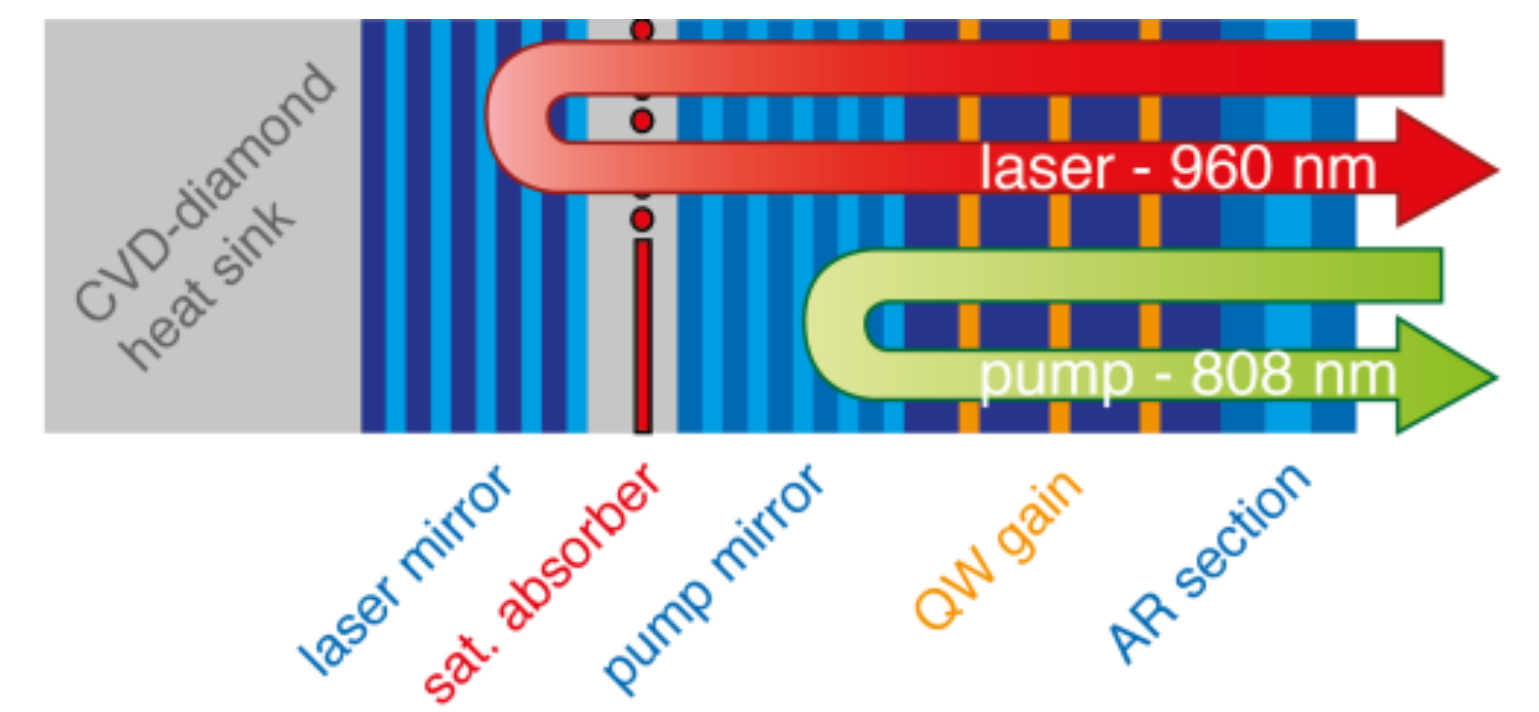
modelocking results

highest output power of a modelocked semiconductor laser [3]

28.1 ps	6.4 W	2.5 GHz
pulse duration	output power	repetition rate

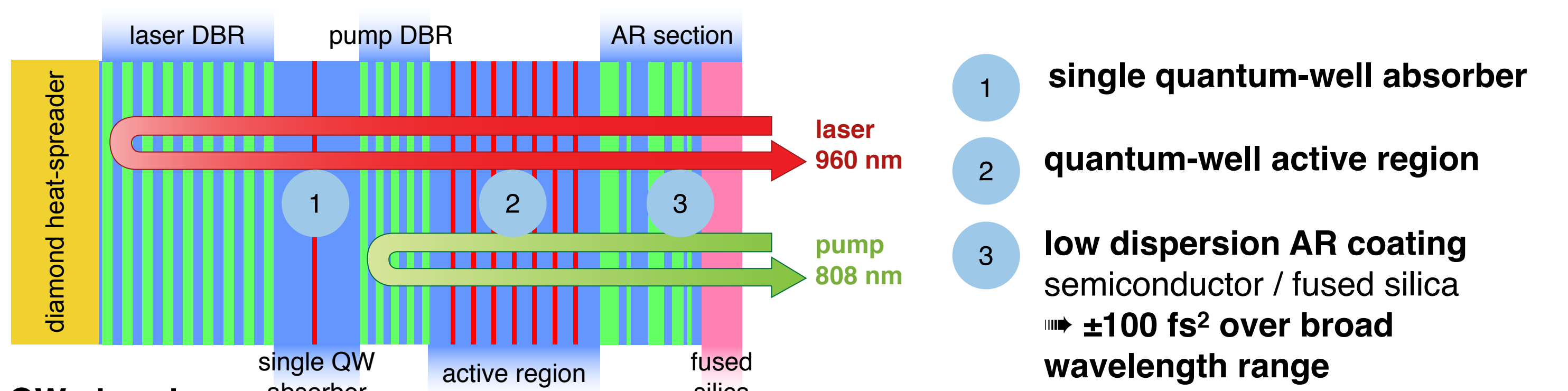
16.9 ps	2.4 W	10 GHz
pulse duration	output power	repetition rate

highest output power of a modelocked 10 GHz semiconductor laser [4]



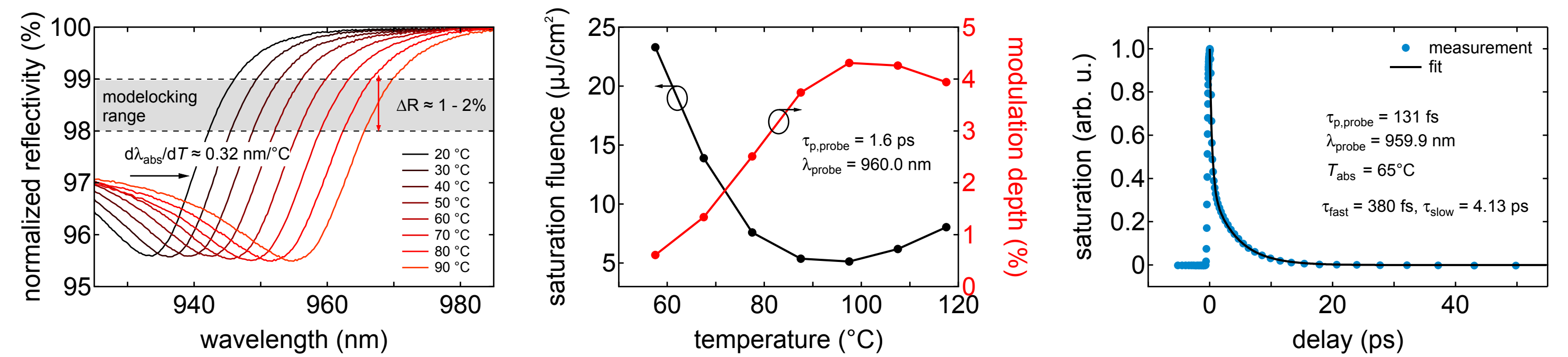
[3] B. Rudin, V. J. Wittwer, D. J. H. C. Maas, M. Hoffmann, O. D. Sieber, Y. Barbarin, M. Golling, T. Südmeyer, and U. Keller, Opt. Exp. (2010) vol. 18, pp. 27582
[4] V. J. Wittwer, M. Mangold, M. Hoffmann, O. D. Sieber, M. Golling, T. Südmeyer, U. Keller, Electronics Lett., vol. 48, No. 18, pp. 1144, 2012

MIXSEL with fast quantum well absorber



QW-absorber MIXSEL

absorber characterization

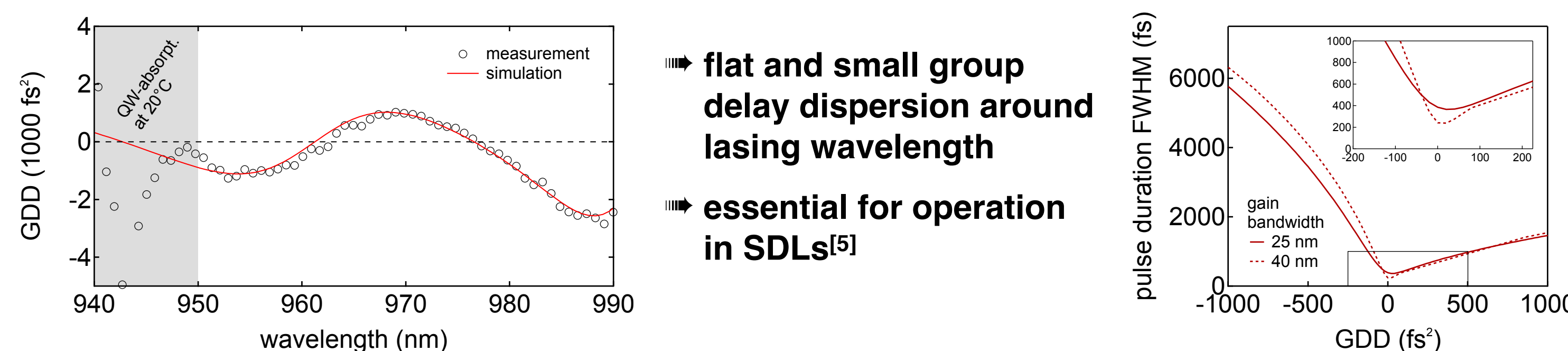


- blue-shifted absorption
- operation near the band-edge

- low saturation fluences at elevated temperatures

- fast absorber recovery despite annealing
- nearly 50 times faster than previous QD-absorber

coating for low group-delay dispersion

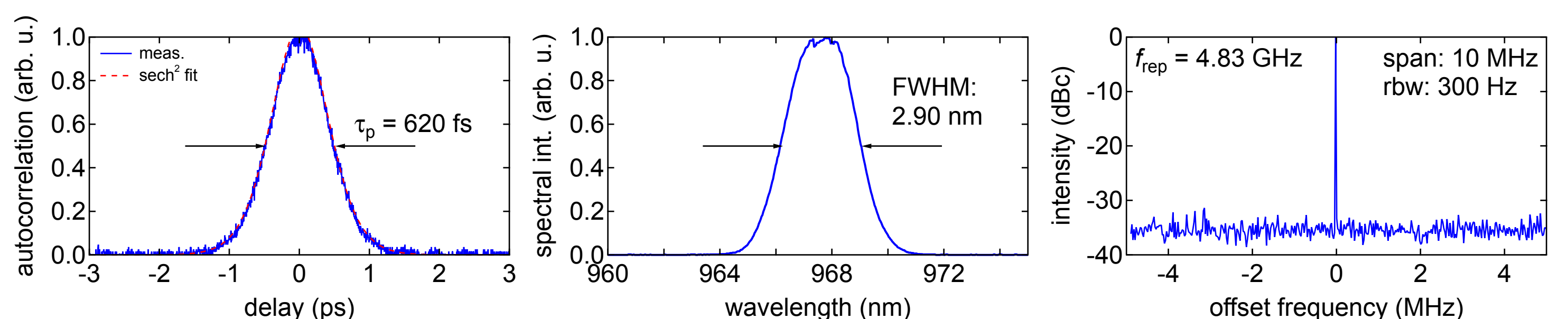
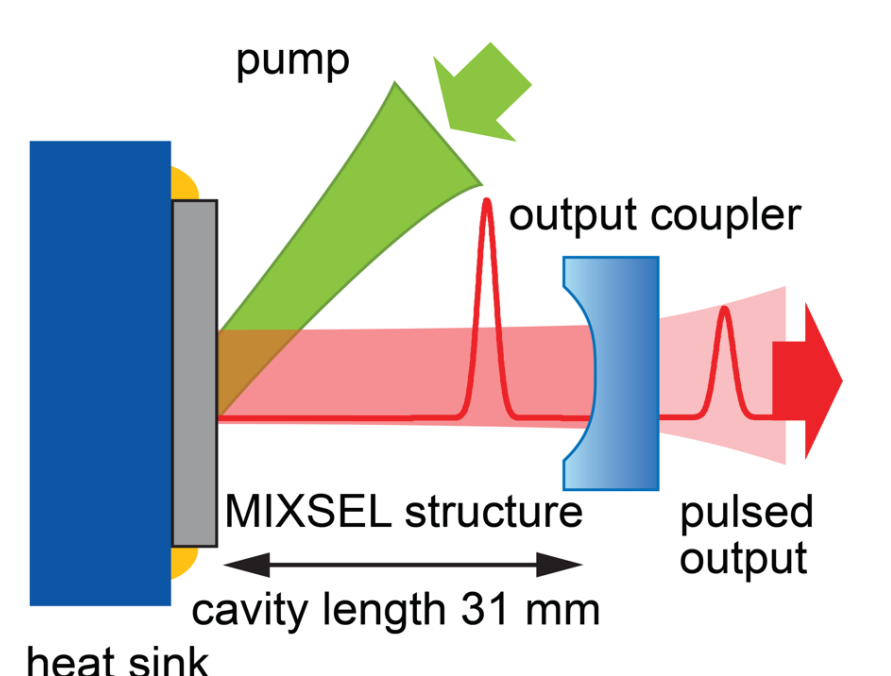


first femtosecond MIXSEL [6]

M. Mangold *et al.*, Optics Express, vol. 21, No. 21, pp. 24904-24911 (2013)

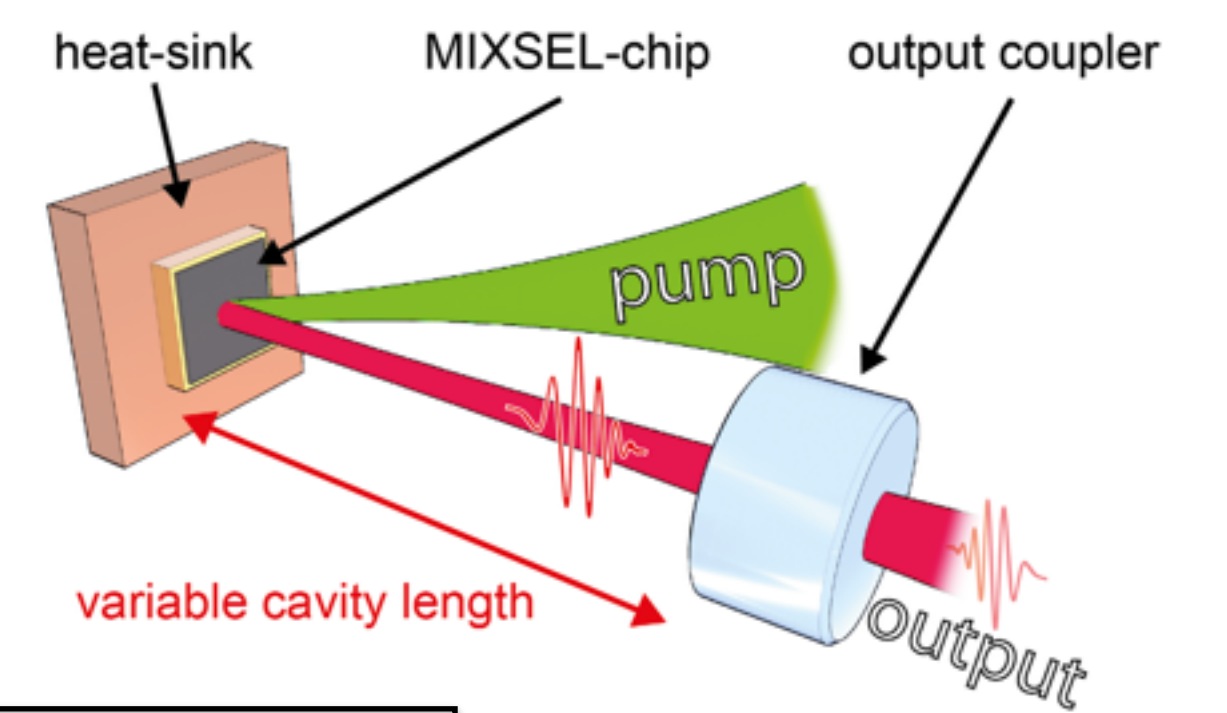
- 25 times shorter pulses than with previous QD-absorber

pulse duration	output power	repetition rate
620 fs	101 mW	4.83 GHz



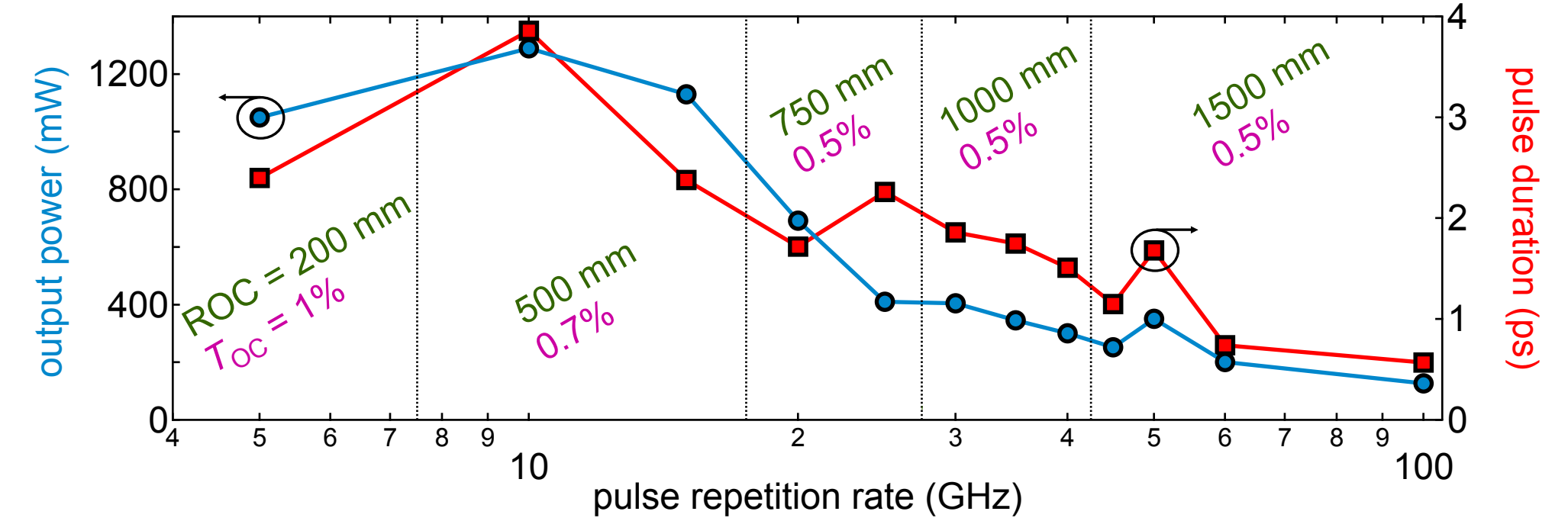
Repetition rate scaling to 100 GHz

- straight cavity for nearly arbitrarily high repetition rates
- negligible Q-switching instabilities for semiconductor gain materials
- integrated absorber: no cavity dependent mode-size difference on gain/absorber

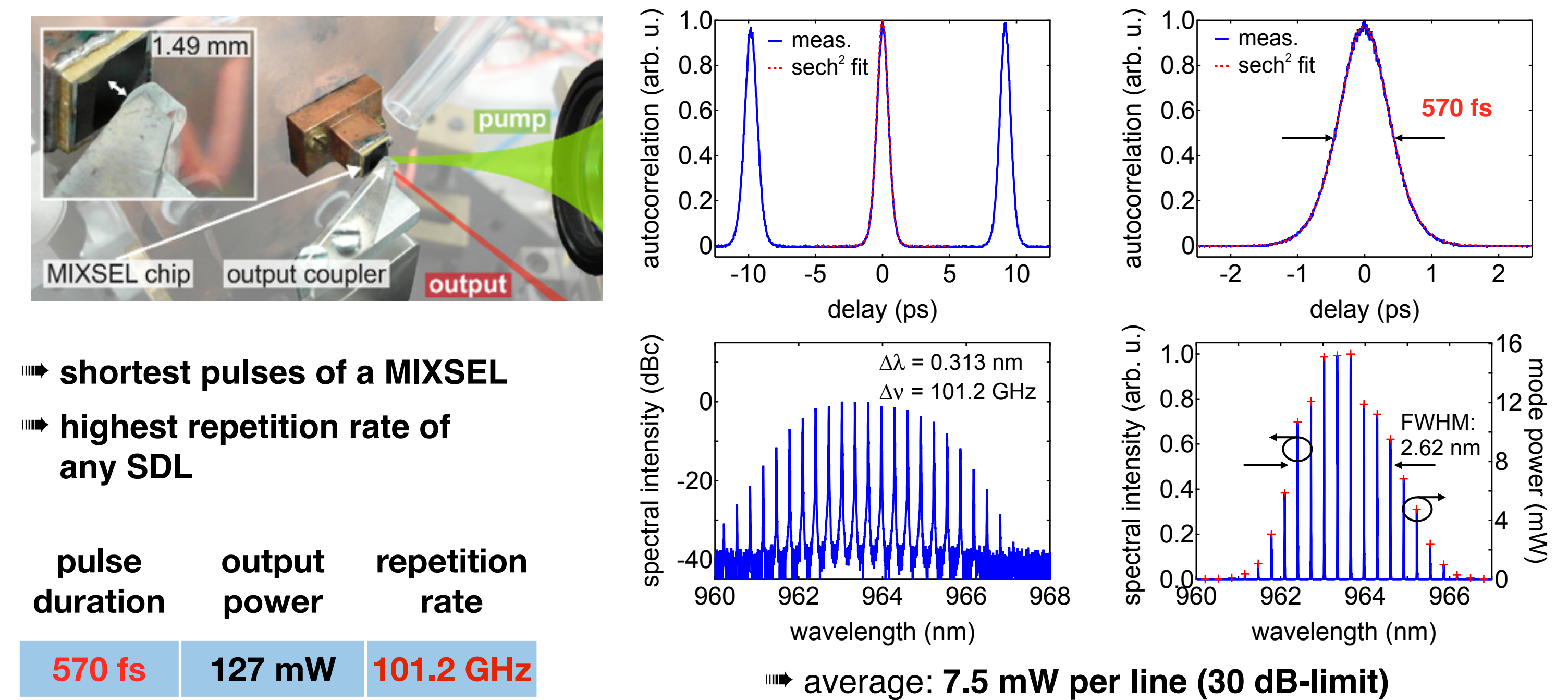


results of repetition rate scaling [7]

- sub-4-ps pulses and watt-level operation up to 15 GHz
- femtosecond operation at 60 GHz and 101 GHz
- excellent beam quality: $M^2 < 1.05$

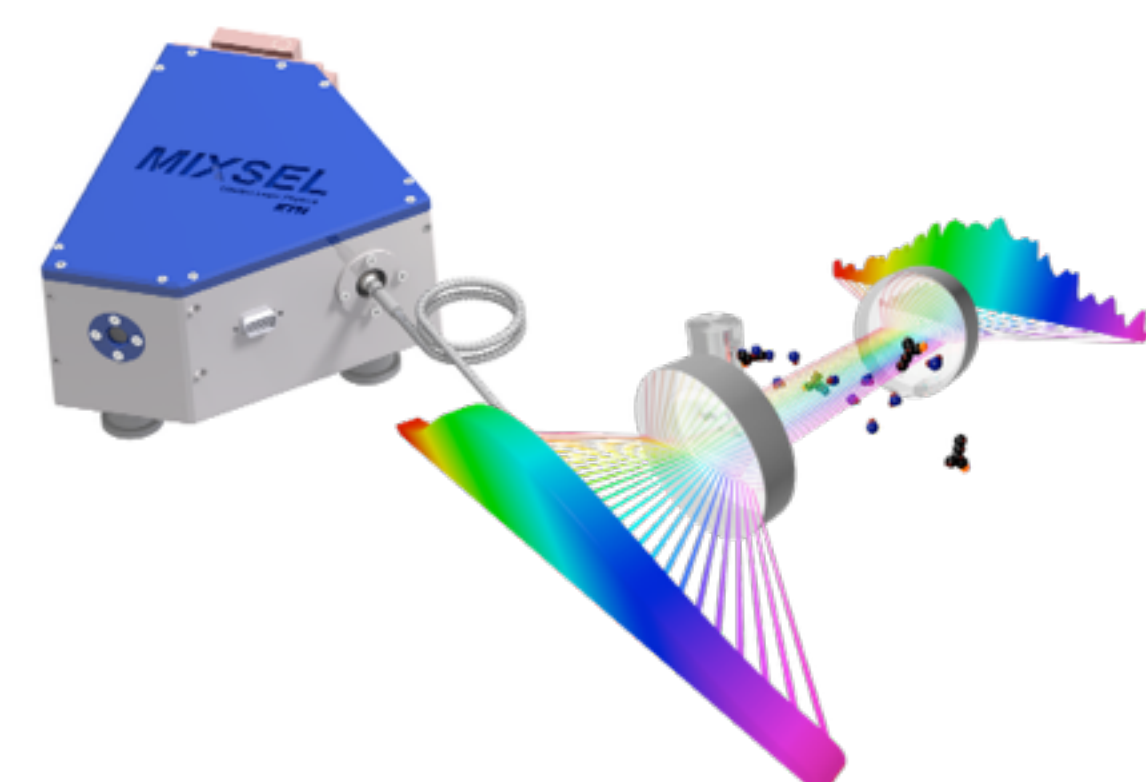


femtosecond 100-GHz MIXSEL



[7] M. Mangold, C. A. Zaugg, S. M. Link, M. Golling, B. W. Tilma, U. Keller, Optics Express, vol. 22, No. 5, pp. 6099-6107, 2014

Outlook



next steps: sub-200-fs pulses with nanojoule pulse energy from a MIXSEL

ultimate goal: fully stabilized frequency comb (repetition rate & CEO-frequency) from a compact, low cost MIXSEL