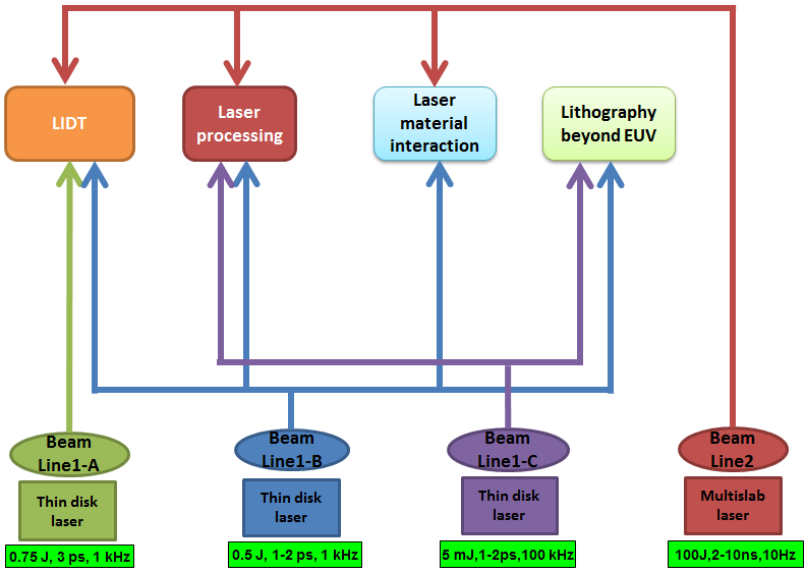
Development of scalable laser technology for EUVL applications

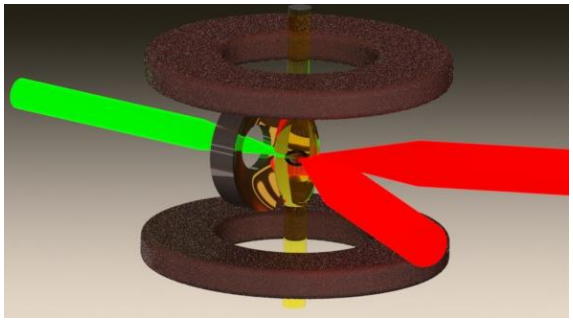
Tomáš Mocek, Ph.D.
Chief Scientist & Project Leader
HiLASE Centre

CZ.1.05/2.1.00/01.0027

Lasers for real-world applications

- Laser induced damage threshold measurement of optical materials
- Laser shock peening
- **Compact X-ray sources for lithography**
- Precise cutting, drilling and welding of special materials for automotive and aerospace industry
- Technology of laser micromachining
- Laser paint stripping, surface cleaning





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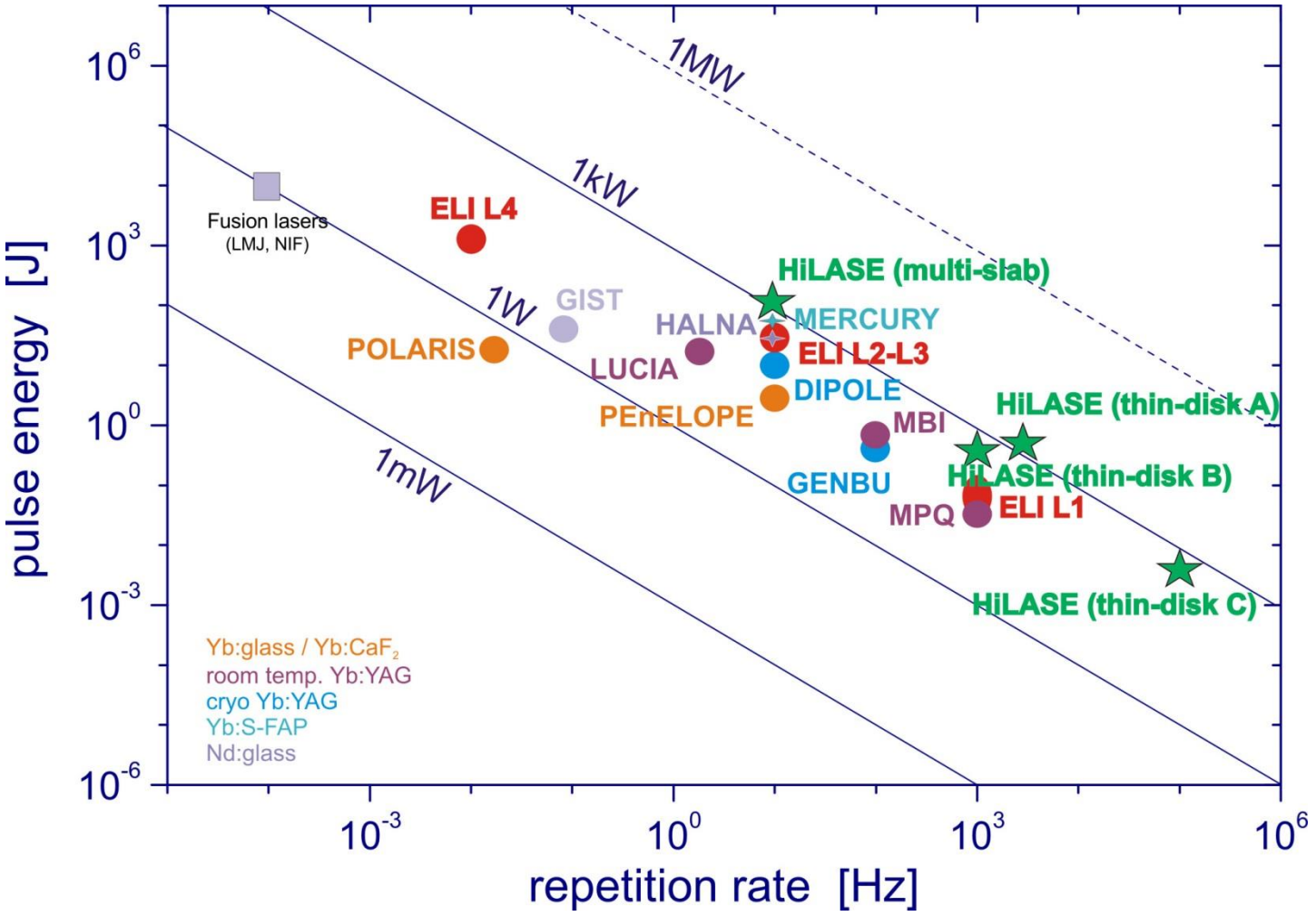
Aiming very high



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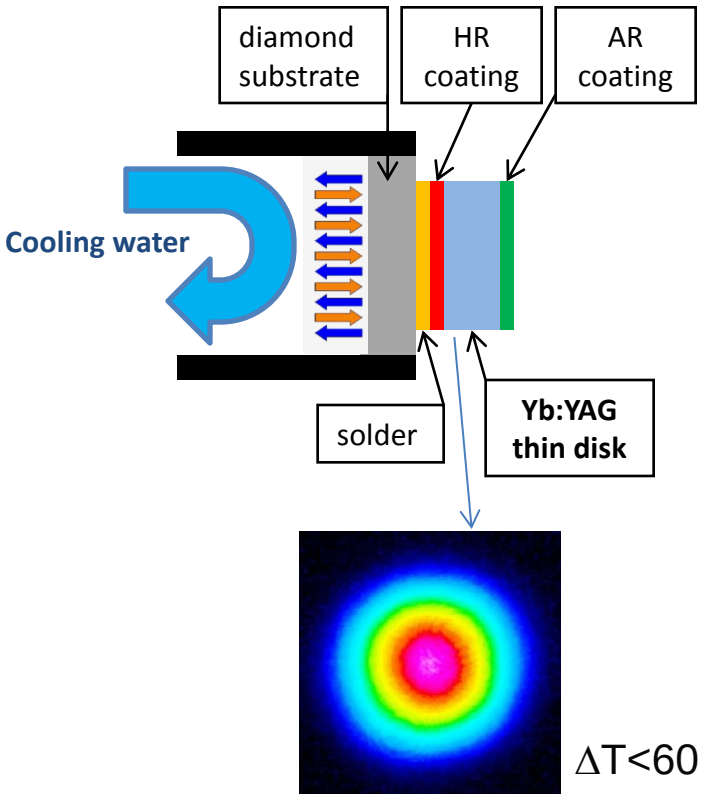
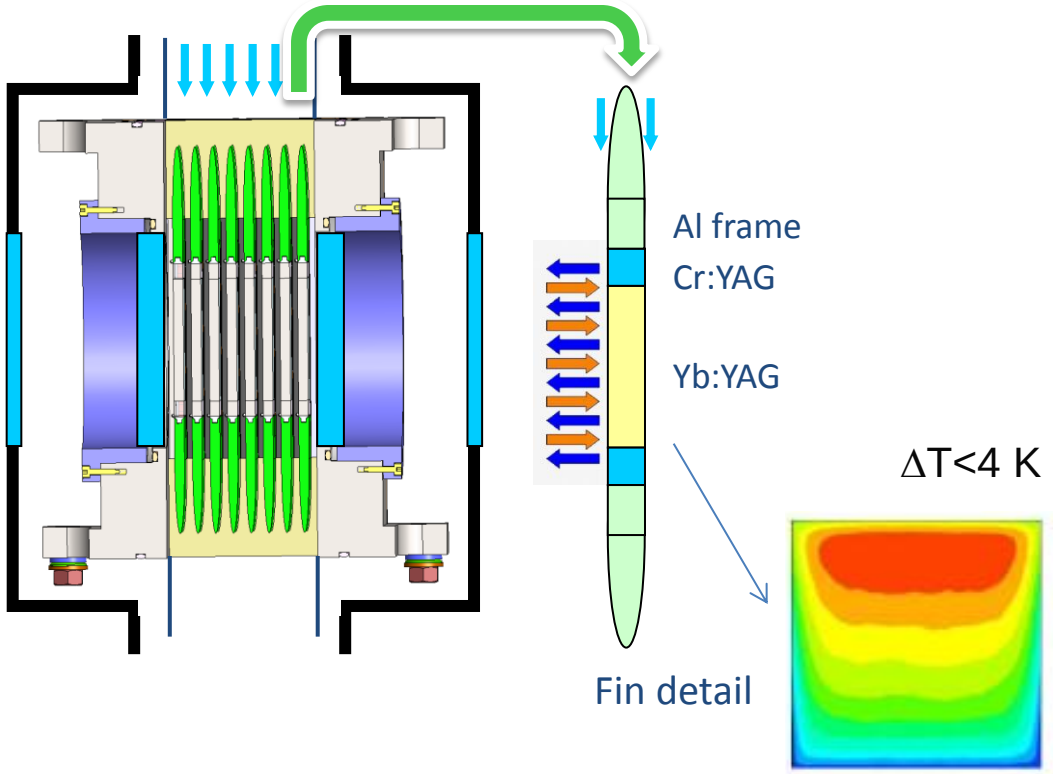
Upscaling novel DPSSL geometries

hilase
Power of light

Thin-disk



Multi-slab



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Development of multi-J, kW class thin-disk laser system (L1)

Prof. Akira Endo

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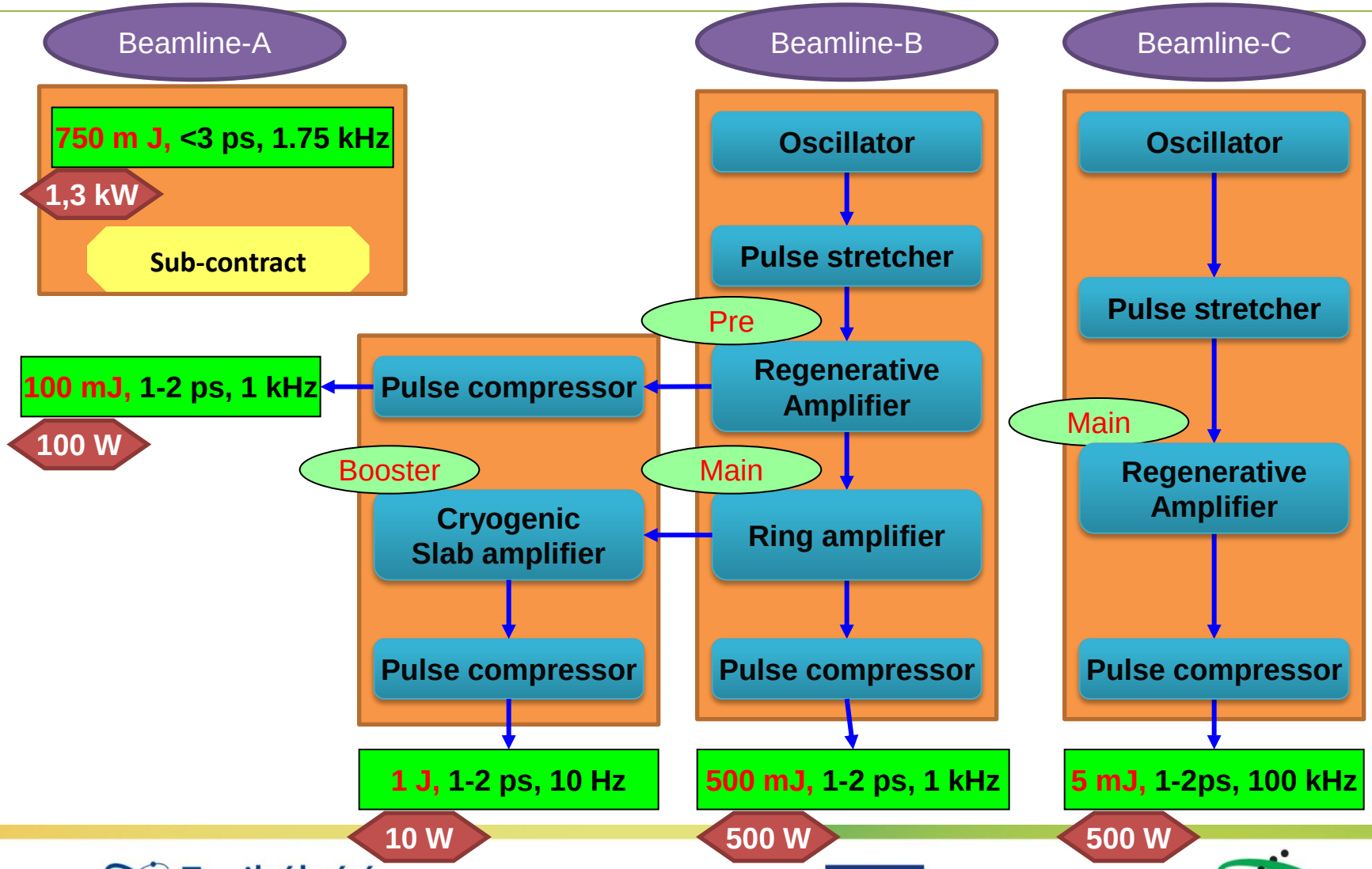
Concept of kW-class thin-disk DPSSL

hilase
Power of light



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Scientific & Industrial applications thin-disk lasers

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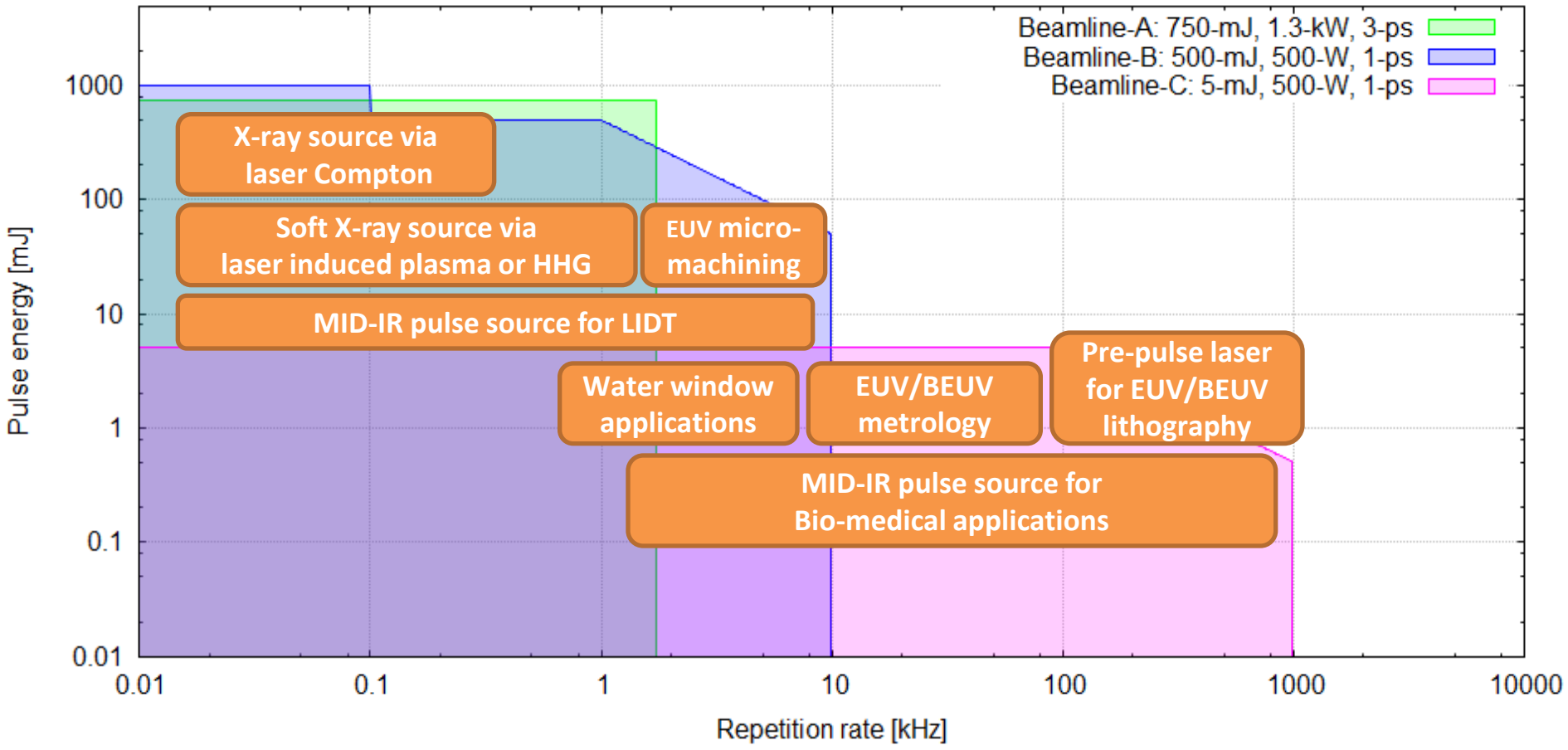
Power of light



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Efficient EUV/BEUV source

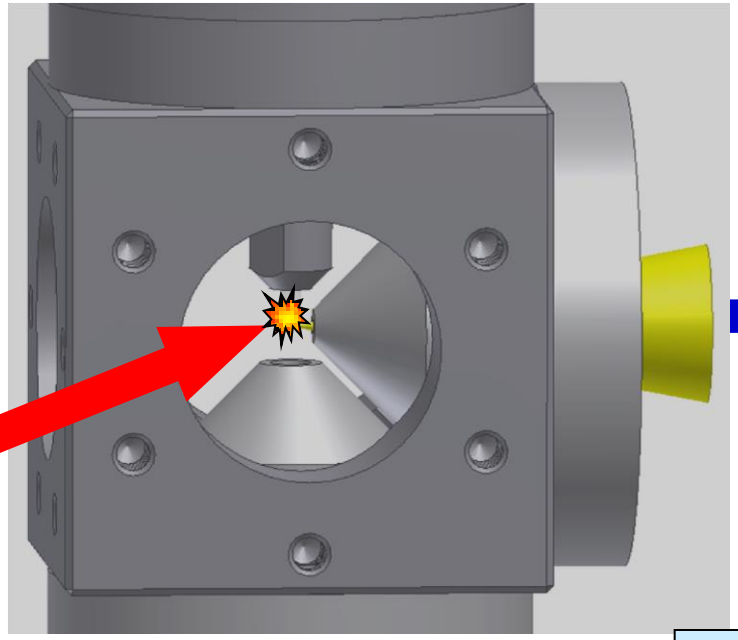
Laser-Laboratorium Göttingen e.V.

hilase Power of light

➢ Continuous dense gas jet target

Xe, Kr, N_2

Differential pumping



Beamline B

ps laser
500 W

New: 0.5 J, 1-2 ps, 1 kHz

Old: 0.5 J, 8 ns, 5 Hz

EUV / BEUV

➢ high brilliance
➢ low debris

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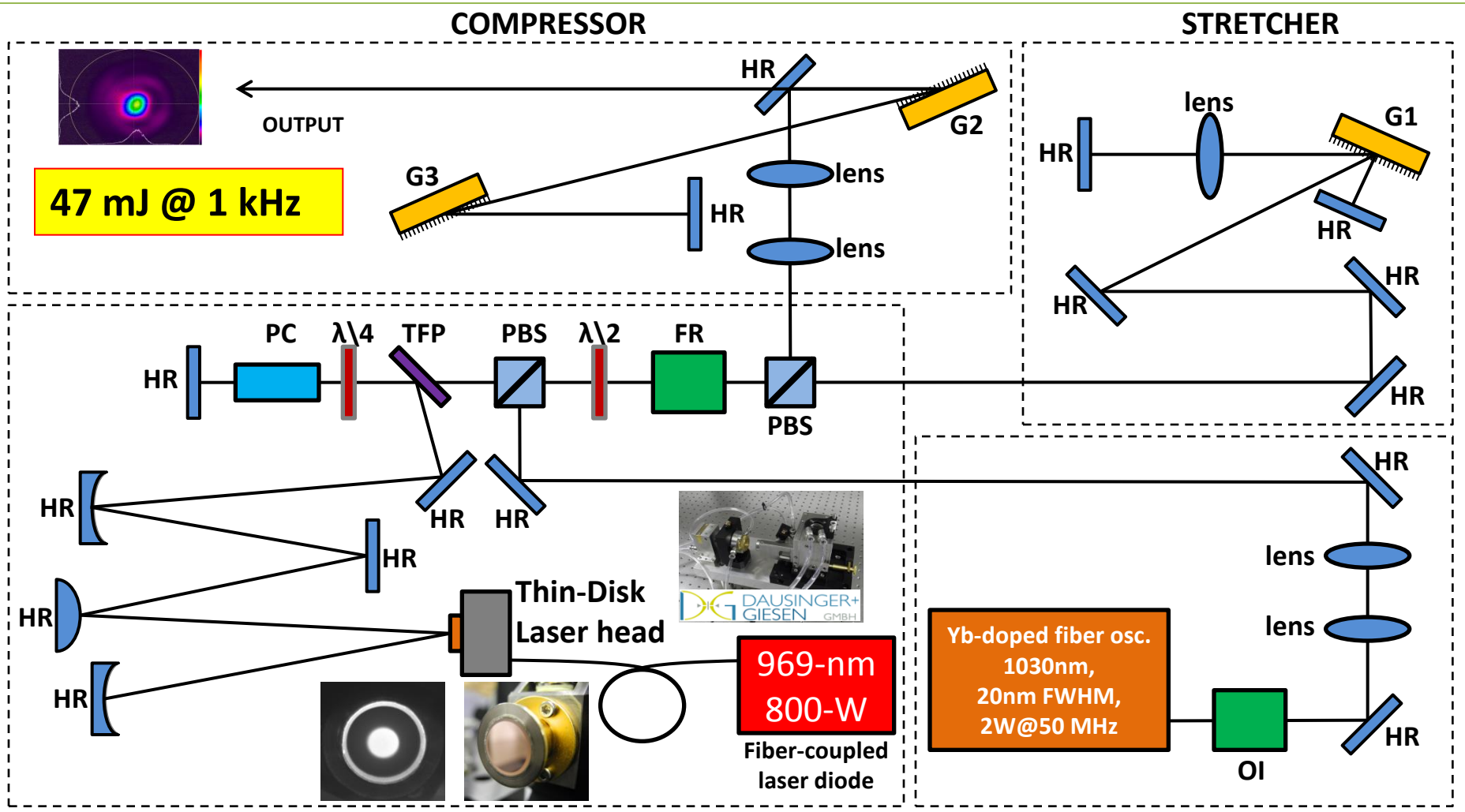
High Energy Regenerative Amplifier with pulsed zero-phonon-line pumping

hilase
Power of light



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969 nm vs. 940 nm pulsed pumping

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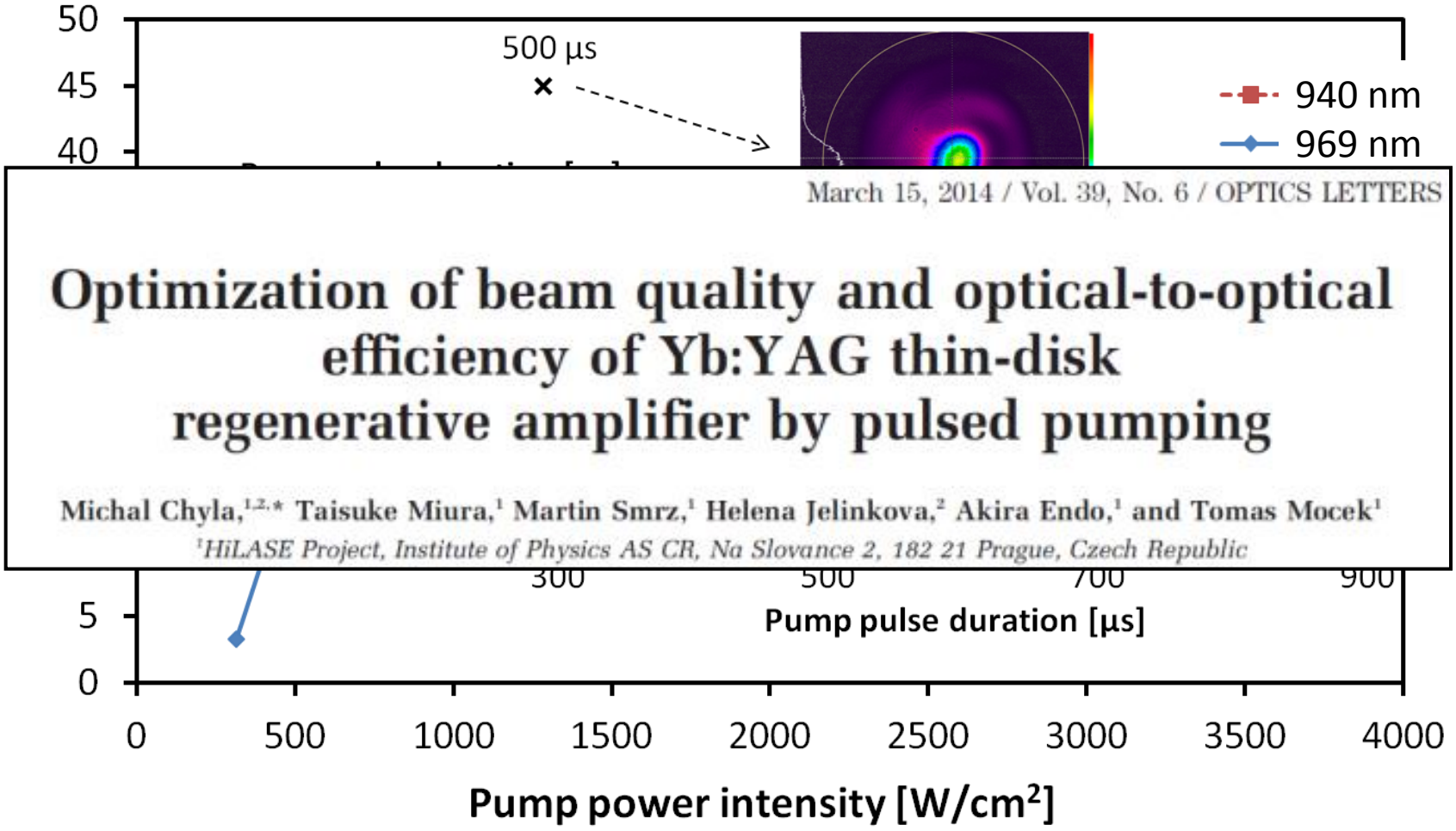
Power of light



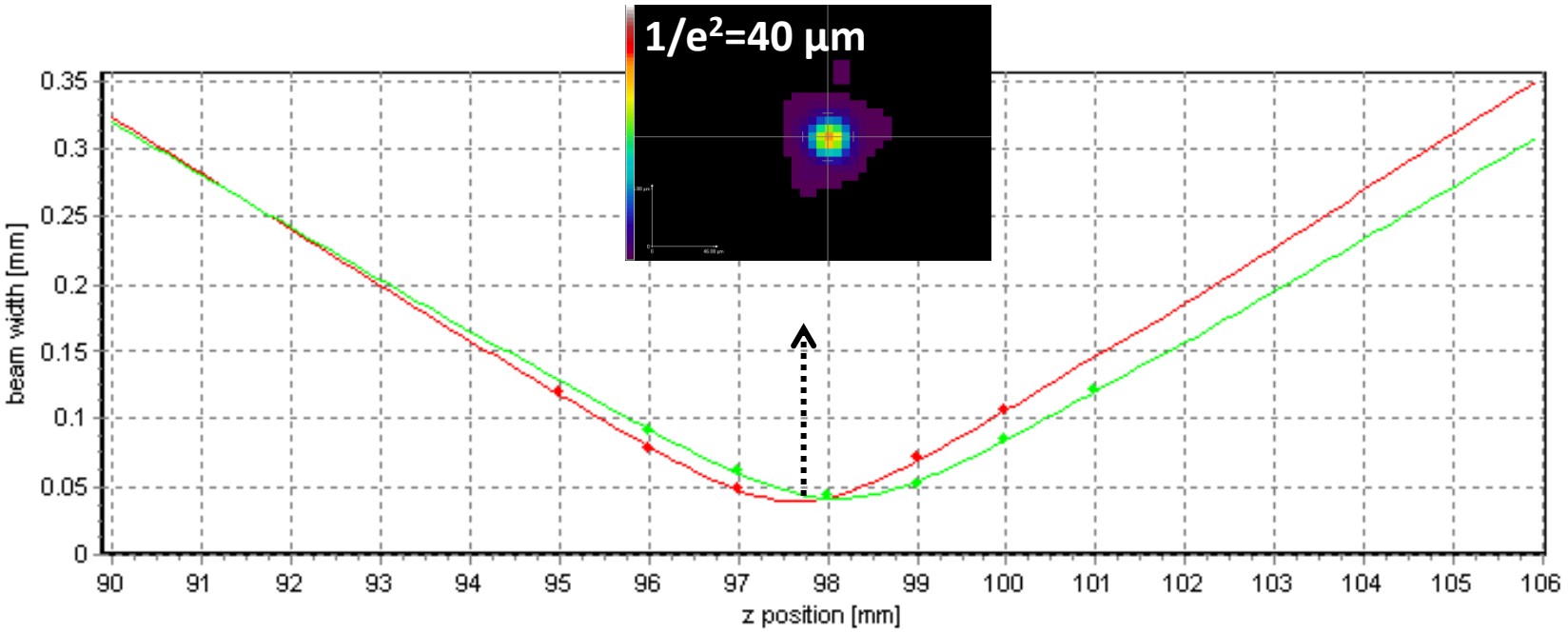
March 15, 2014 / Vol. 39, No. 6 / OPTICS LETTERS

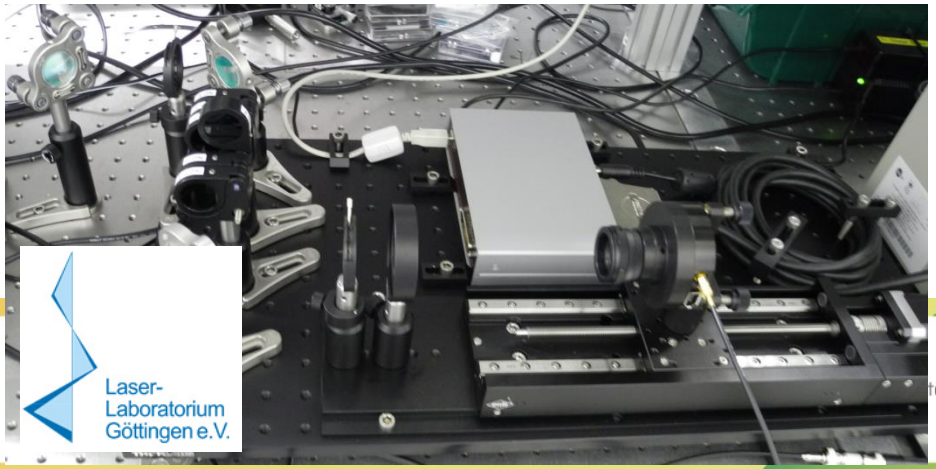
Optimization of beam quality and optical-to-optical efficiency of Yb:YAG thin-disk regenerative amplifier by pulsed pumping

Michal Chyla,[1,2,*] Taisuke Miura,[1] Martin Smrz,[1] Helena Jelinkova,[2] Akira Endo,[1] and Tomas Mocek[1]

[1]HiLASE Project, Institute of Physics AS CR, Na Slovance 2, 182 21 Prague, Czech Republic

M^2 measurement of Beamline B





M^2	
Horizontal	Vertical
1.25	1.23

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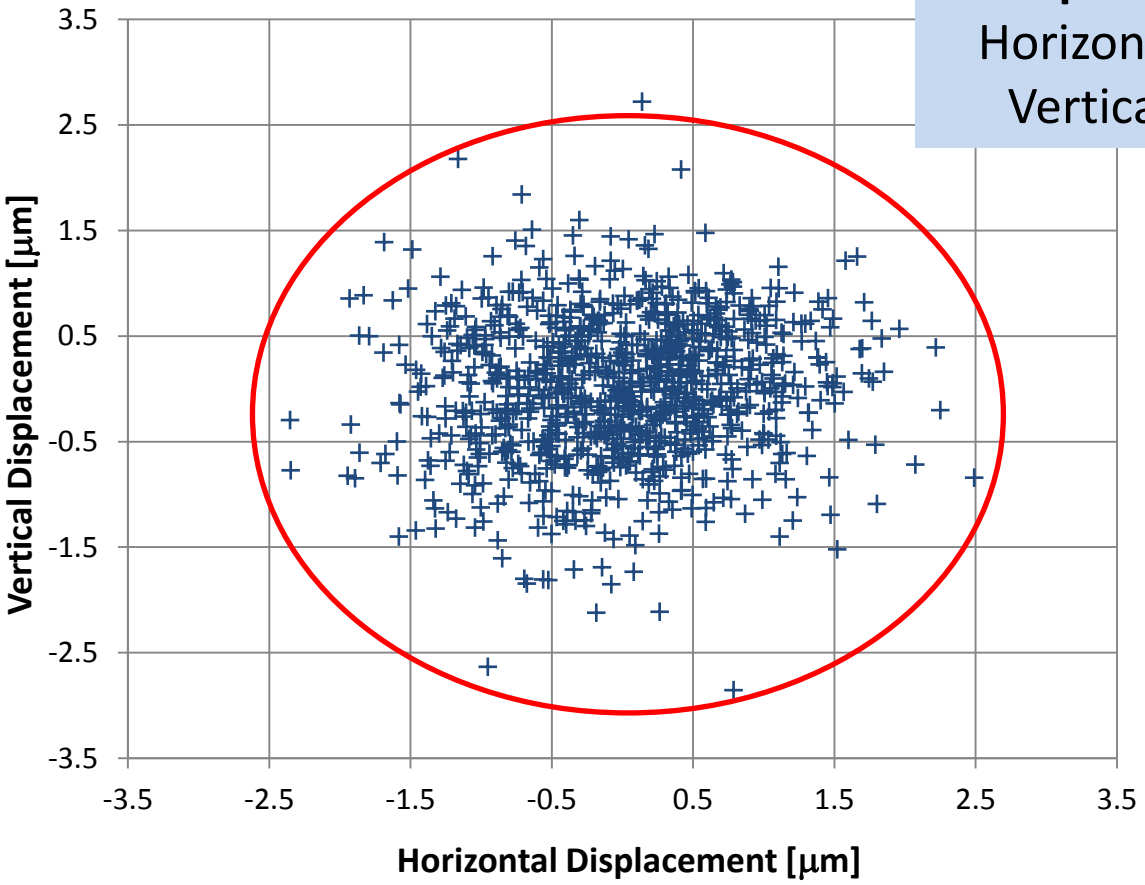
Beam pointing stability

RMS pointing stability:
Horizontal- **3.8 µrad**
Vertical- **3.3 µrad**



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Pre-pulse Laser for HVM EUV Lithography

hilase
Power of light

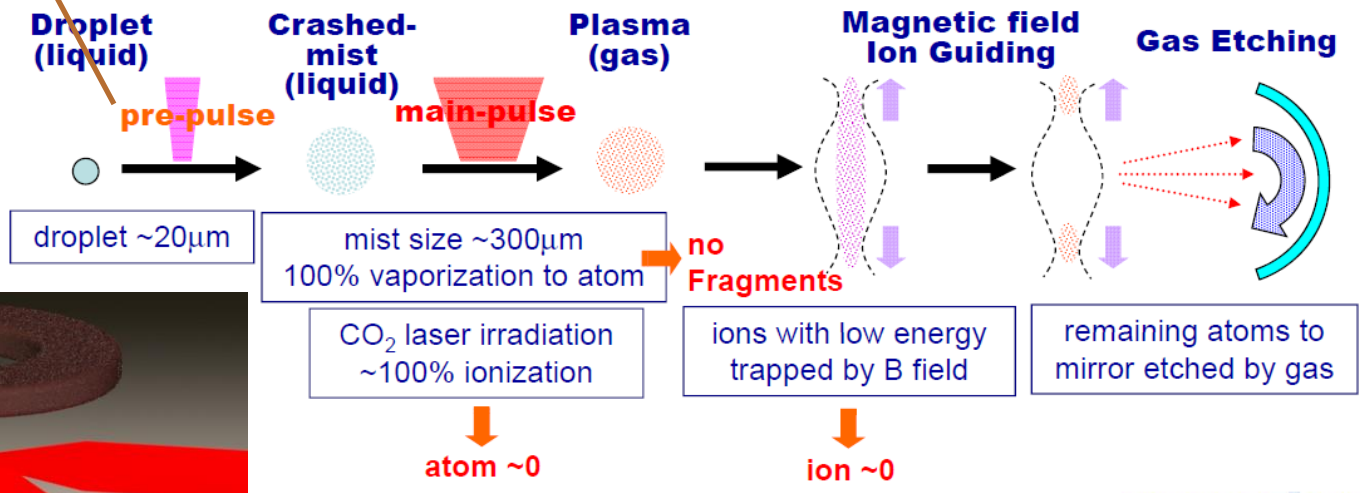
GIGAPHOTON

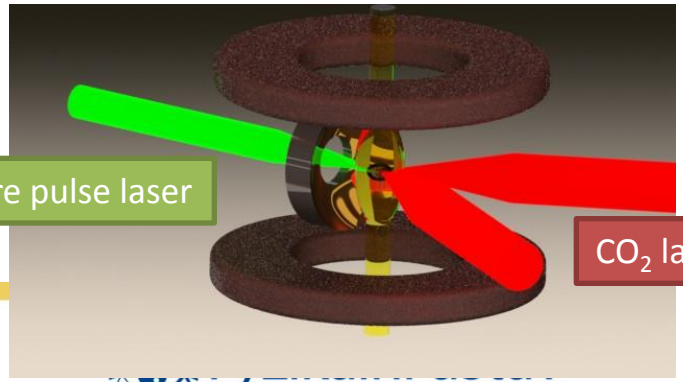
- Solid-state laser
- 3.3 mJ
- 150 kHz
- (500 W)
- <10 ps

Beamline C

Debris mitigation concept

- Double pulse laser irradiation
- Magnet field is effective for guiding ions
- Gas etching





Pre pulse laser

CO_2 lasers

KOMATSU

[8322-14] SPIE 2012 Advanced Lithography, February 14, 2012, P11

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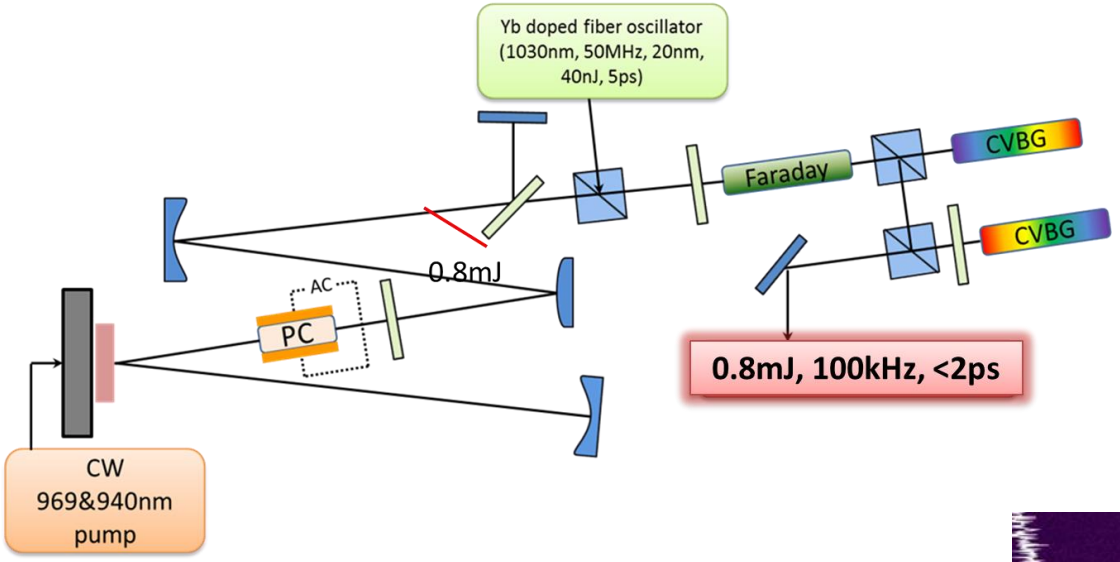
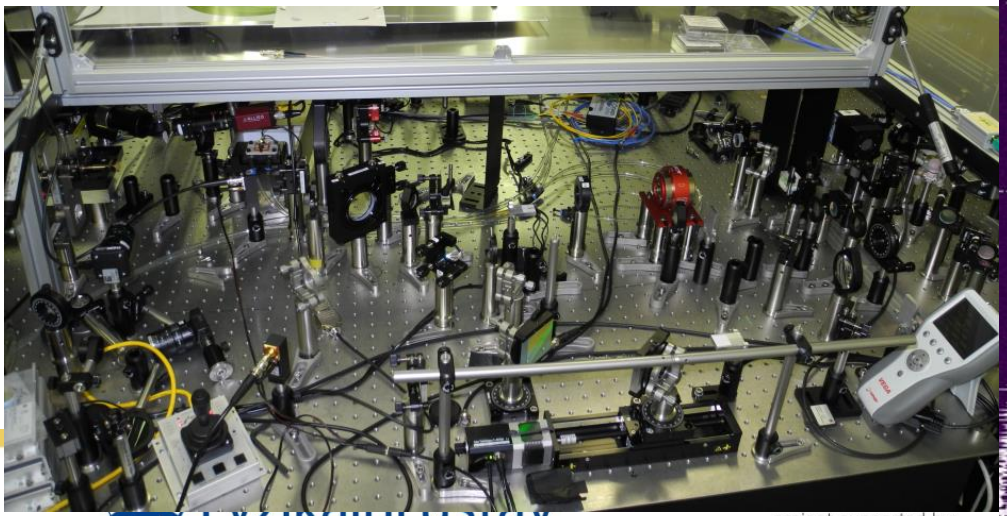
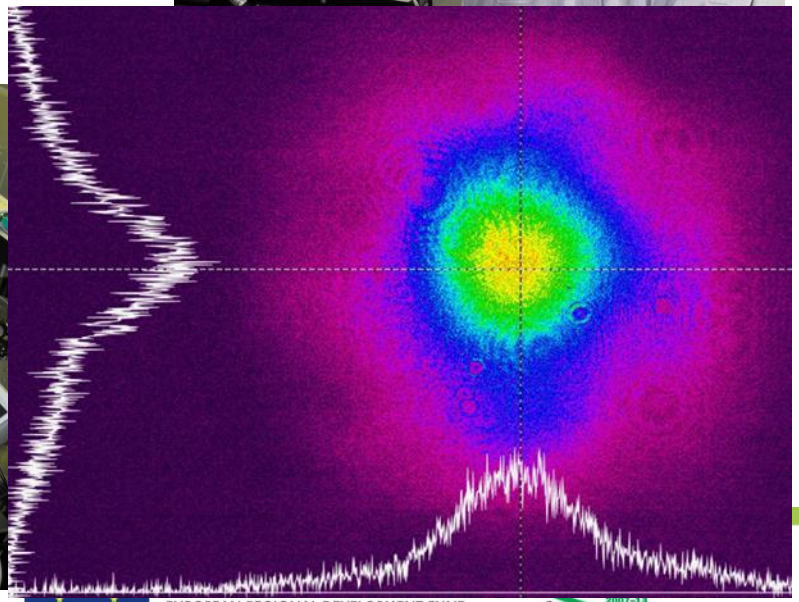
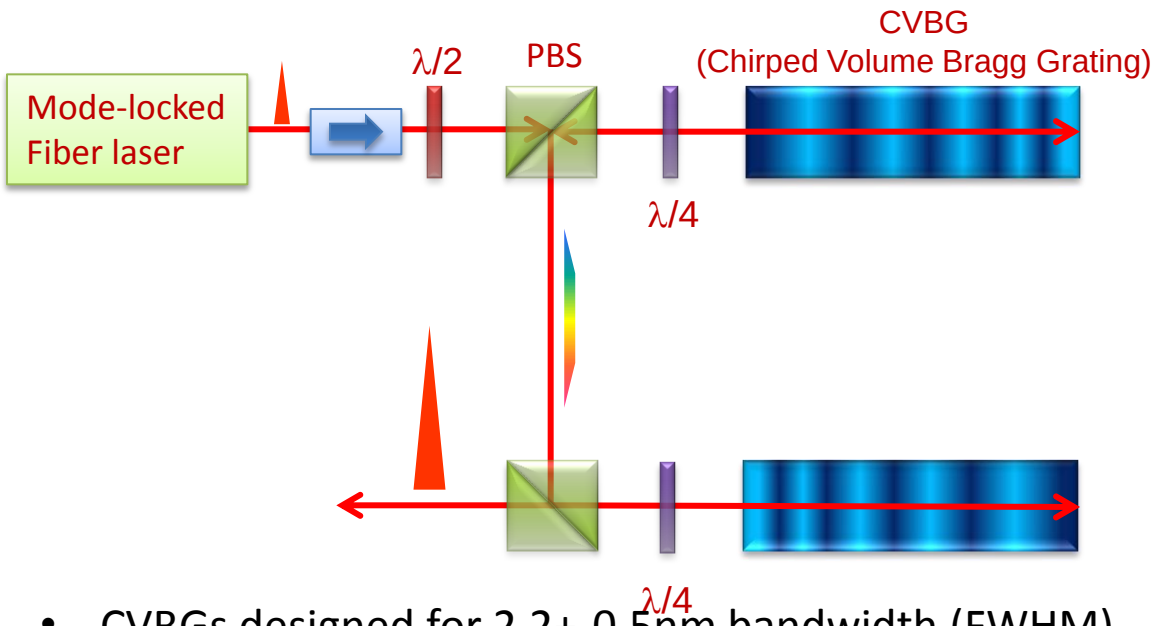
Beamline C: upgraded to 85W (02/2014)

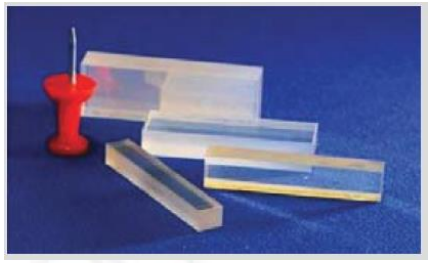




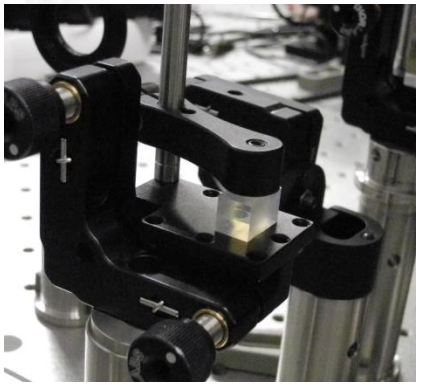


CVBG-based Pulse Stretcher and Compressor





OptiGRATE
HIGH EFFICIENCY FOR HIGH POWER



- CVBGs designed for 2.2+-0.5nm bandwidth (FWHM)
- Aperture 8x8mm
- 180 ps/nm dispersion
- 88% diffraction efficiency
- Oscillator bandwidt approx. 20nm, i.e. 78.5% pulse energy losses in stretcher
- Home-made oscillator is being developed
- Compressor (grating) efficiency 87 - 88% (measured)

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Beamline C: compressed pulse <2 ps

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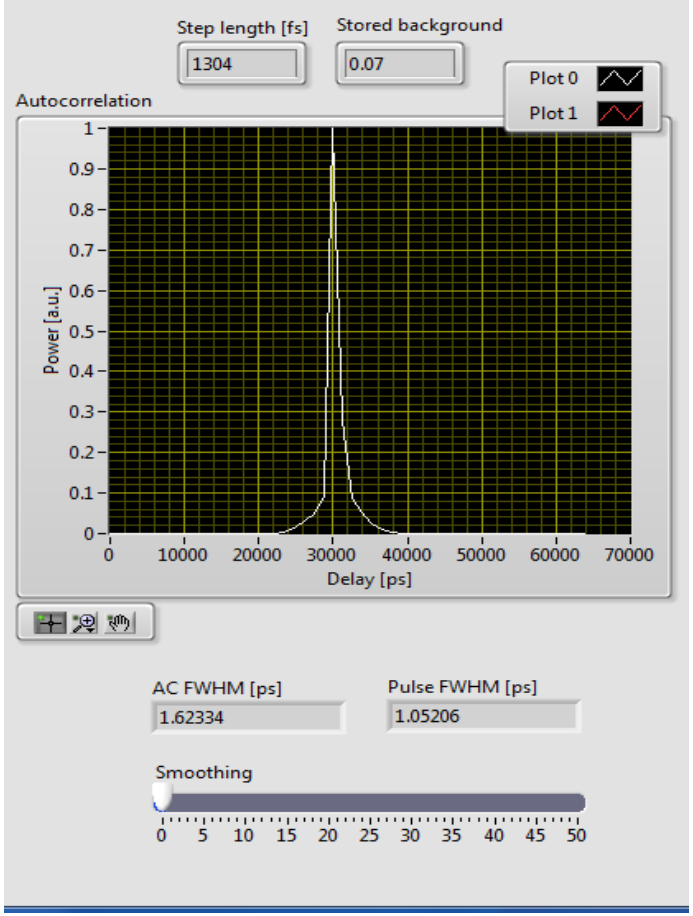
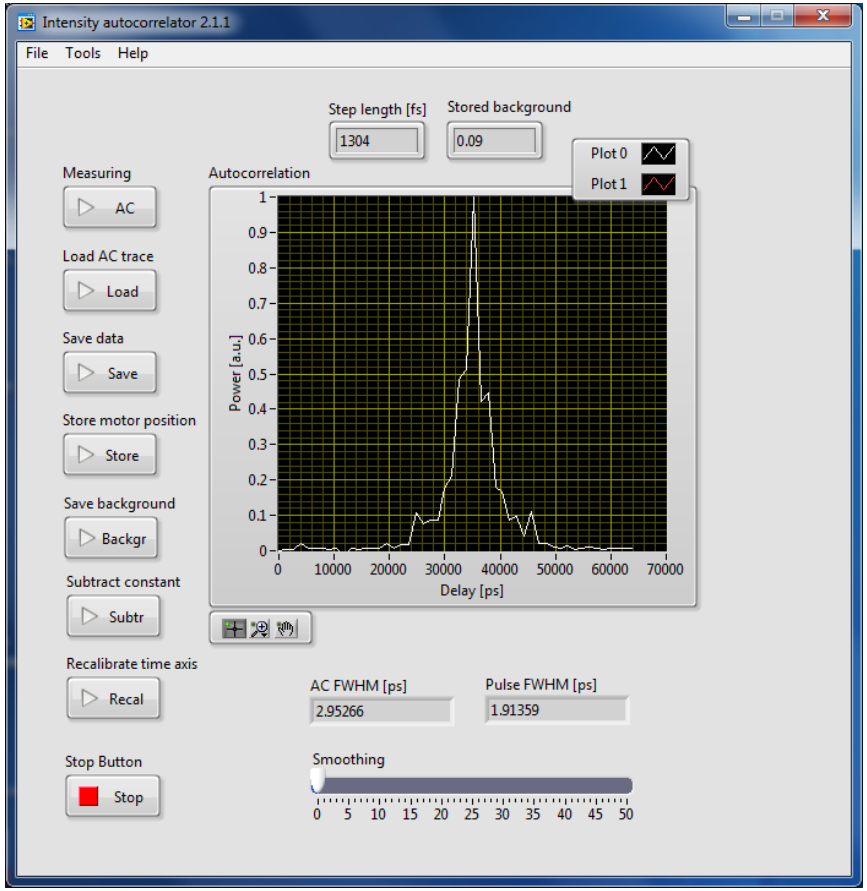
Power of light

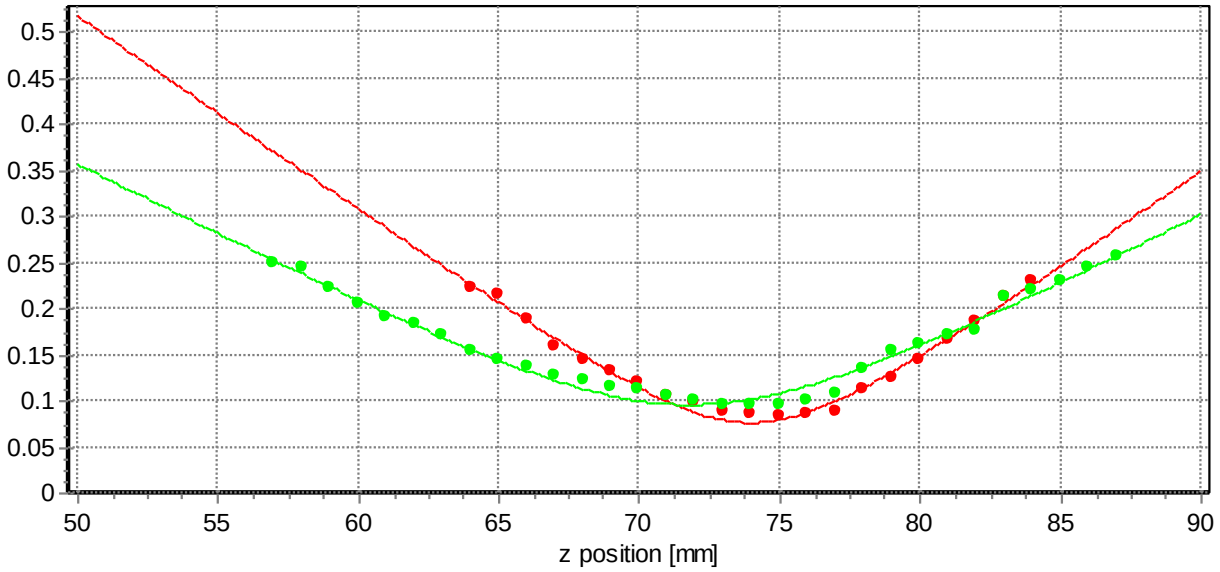
oscillator



CVBGs + regen + precompressor



M^2 measurement of Beamline C



X-direction		Y-direction	
Waistdiameter	0.12 mm	Waistdiameter	0.15 mm
Rayleigh Range	8.74 mm	Rayleigh Range	15.77 mm
Divergence	13.67 mrad	Divergence	9.80 mrad
M_{ζ}	**1.25**	**M_{ζ}**	**1.15**

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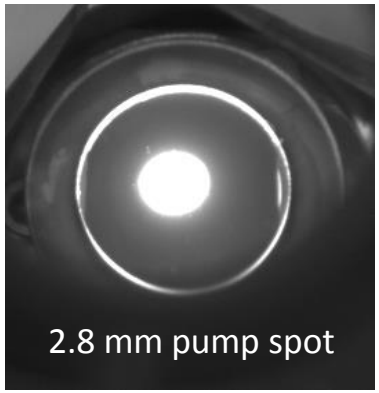
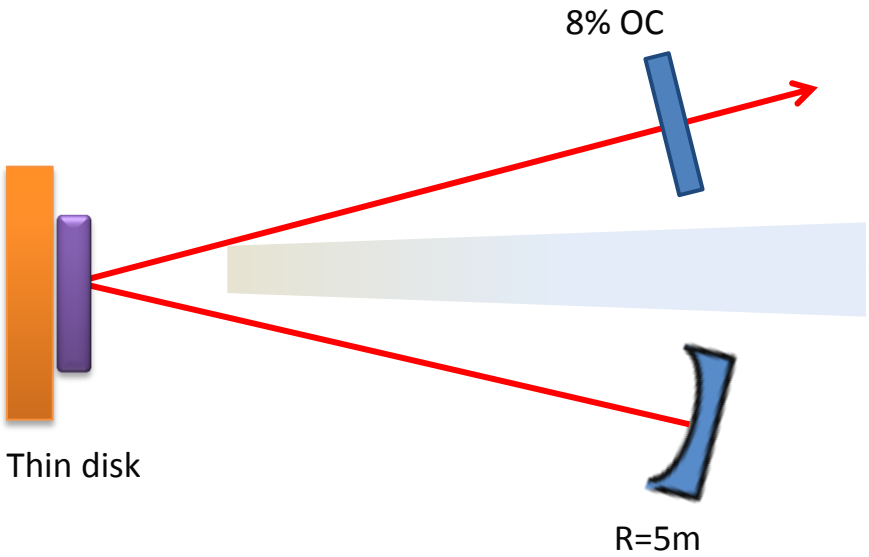
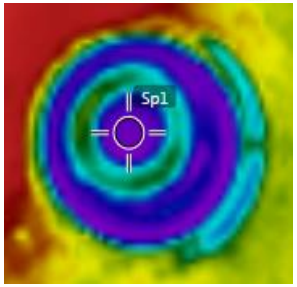
Evaluation of Various Thin Disks (in CW Multimode Laser Cavity)

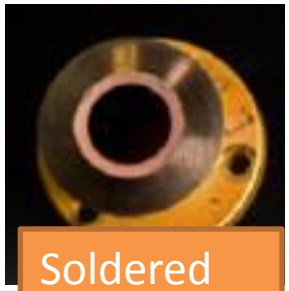
hilase
Power of light



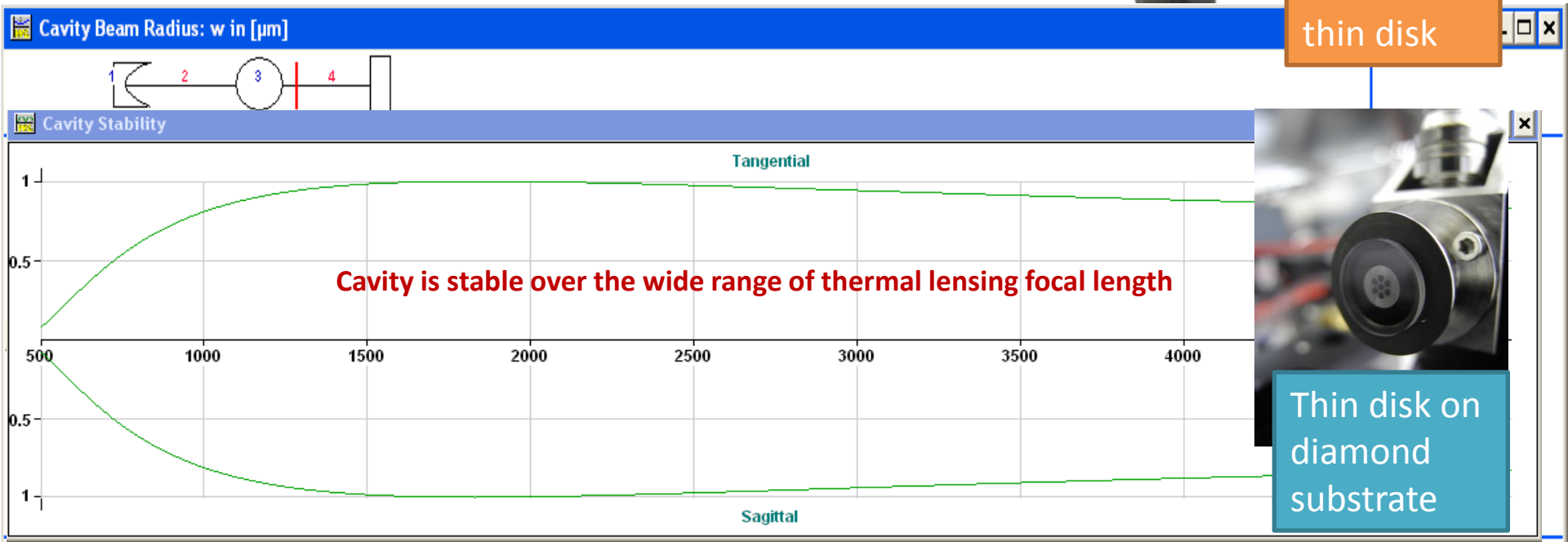


Thermal camera





Soldered thin disk

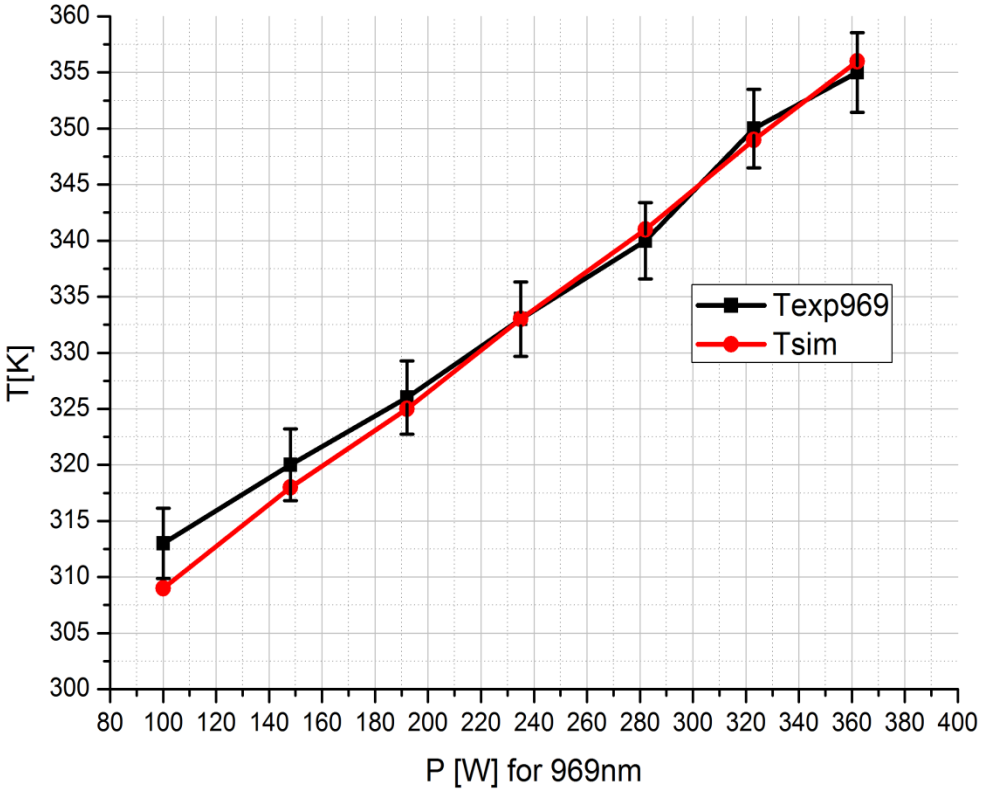


Cavity is stable over the wide range of thermal lensing focal length

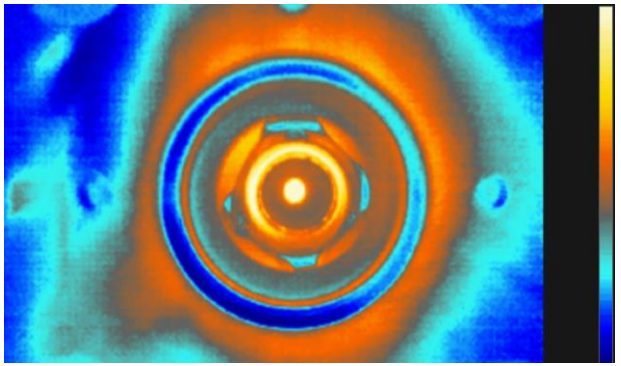
Thin disk on diamond substrate

Comparison Between Numerical Results and Thermal Measurement under CW pumping

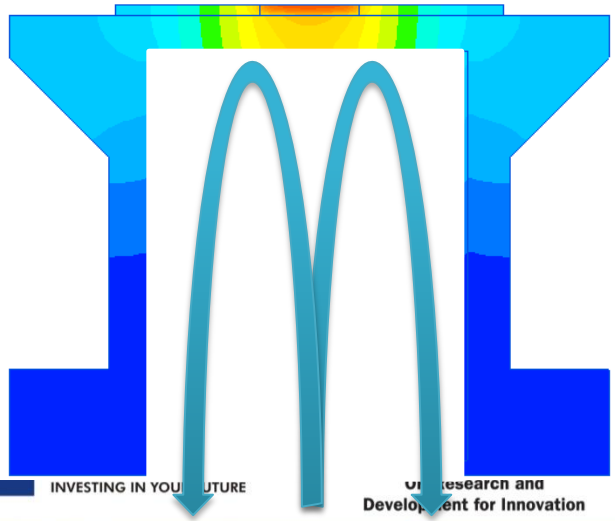
hilase
Power of light



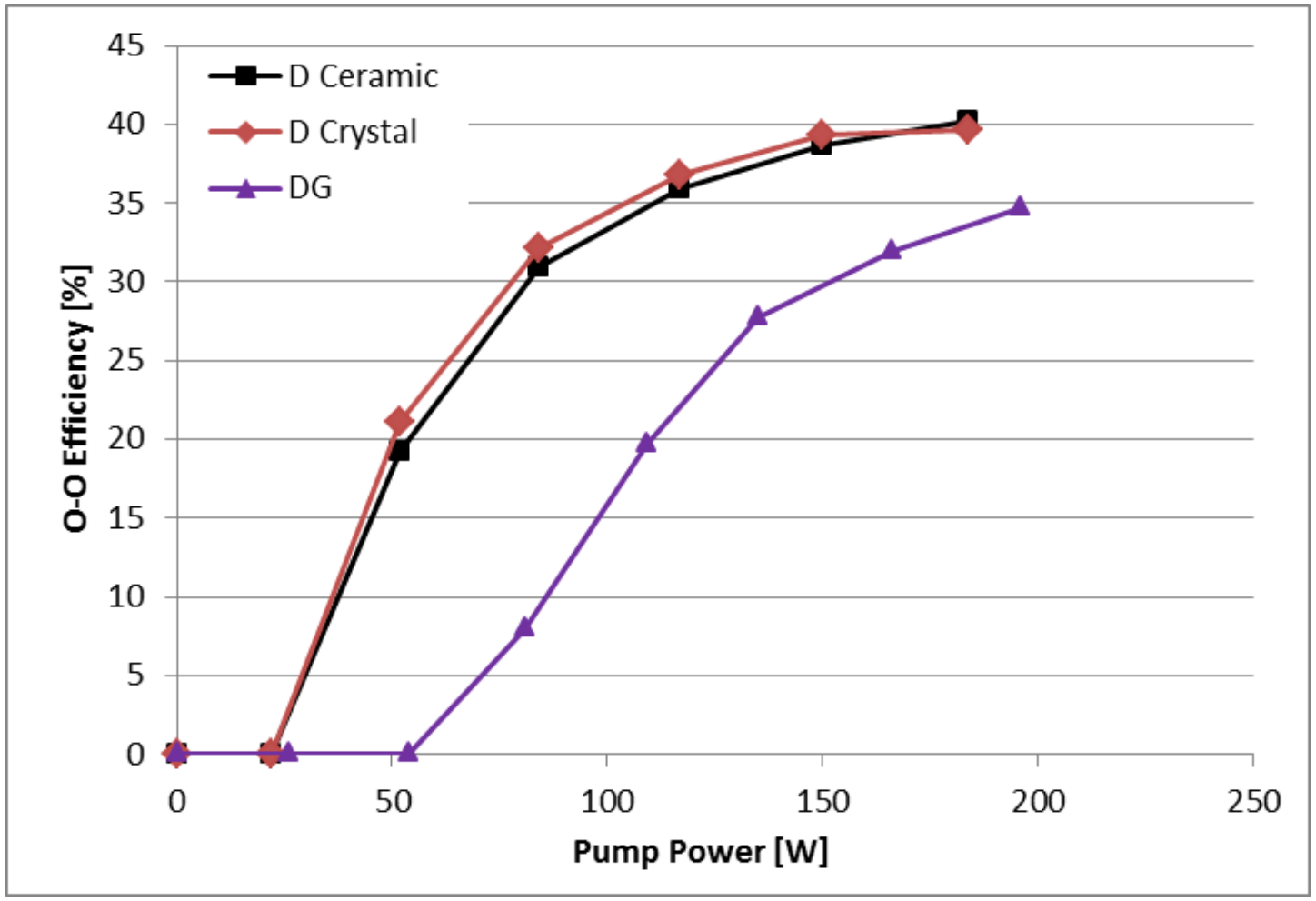
Thermal Image of Yb:YAG thin disk



Numerical calculation of
thin disk temperature distribution



Optical-to-optical efficiency



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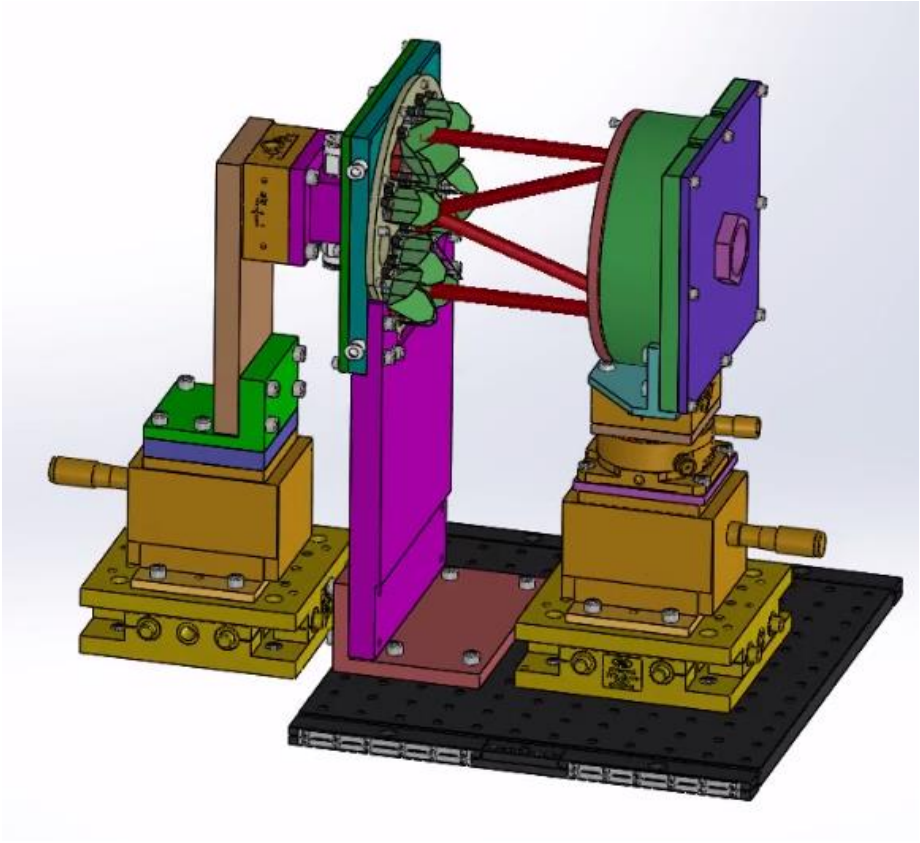
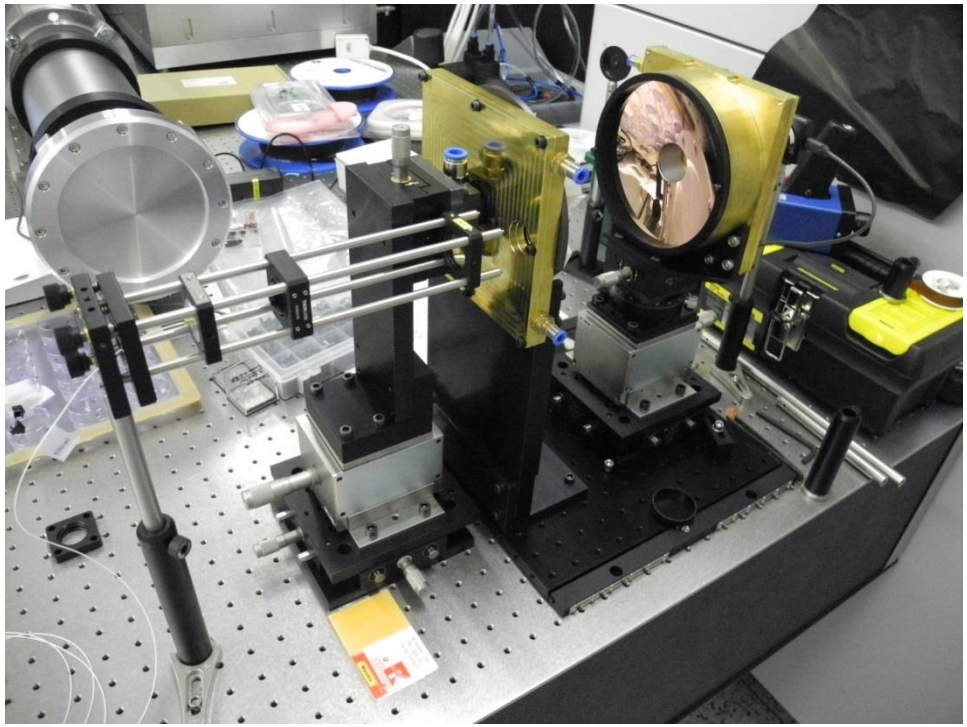
HiLASE Original Thin Disk Head for 5-kW Pumping





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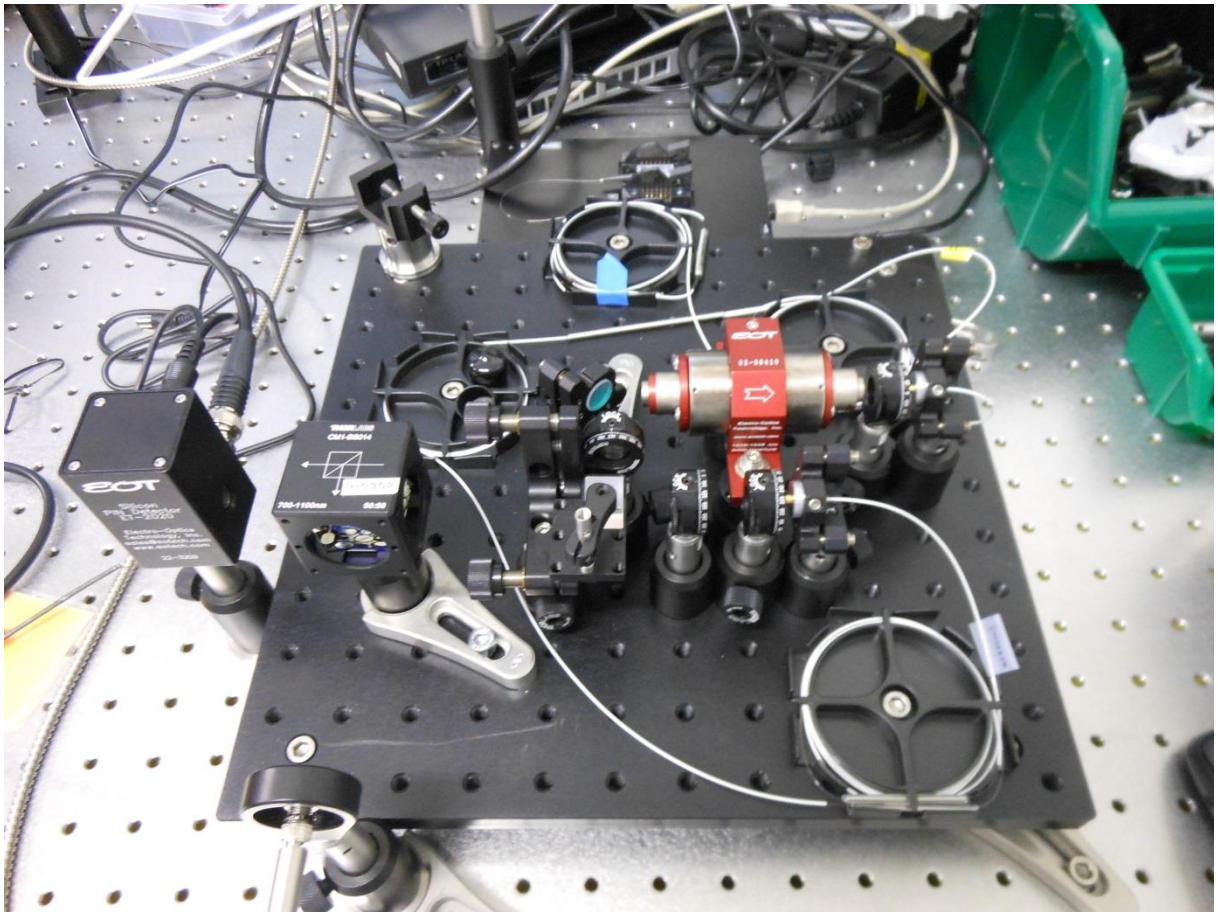
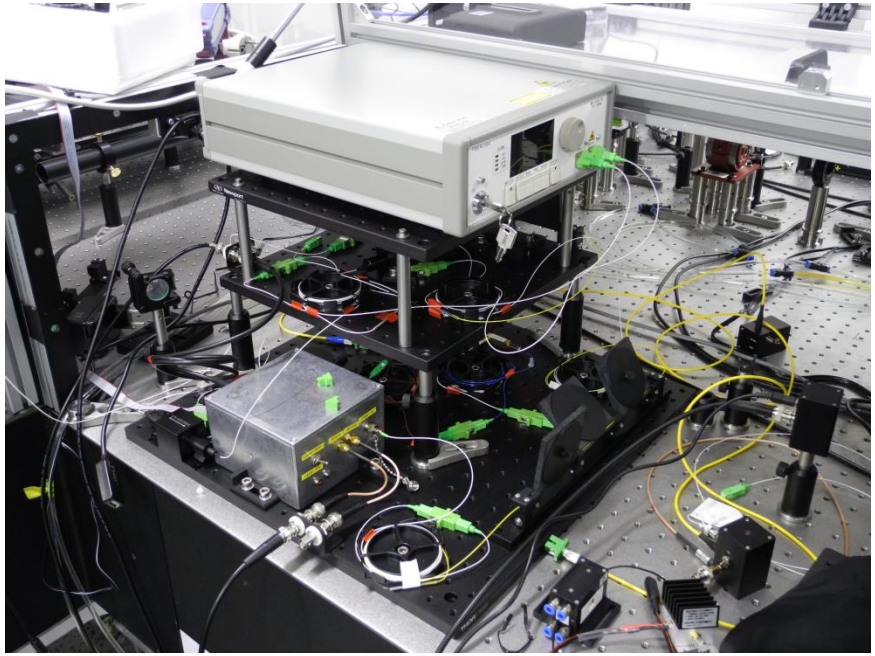
Home-made Yb-doped mode-locked fiber laser

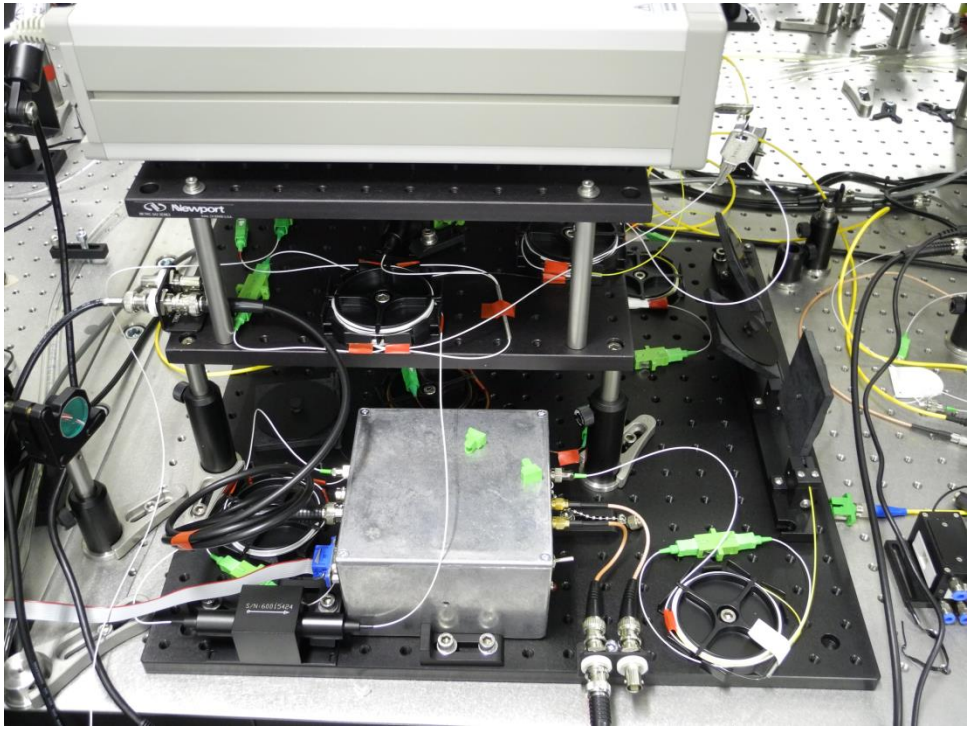
hilase
Power of light



Home-made Fiber-Based Preamplifier

- CFBG stretcher
- SOA pulse picker + YDFA amplifier





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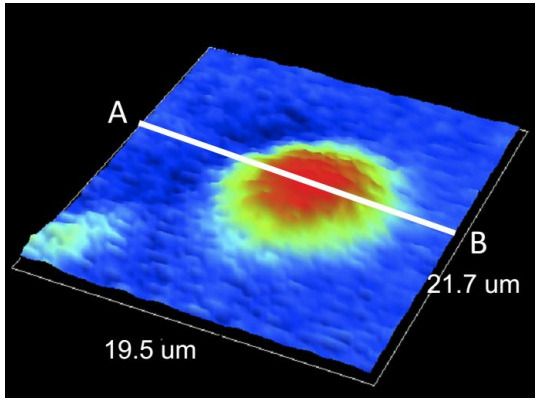
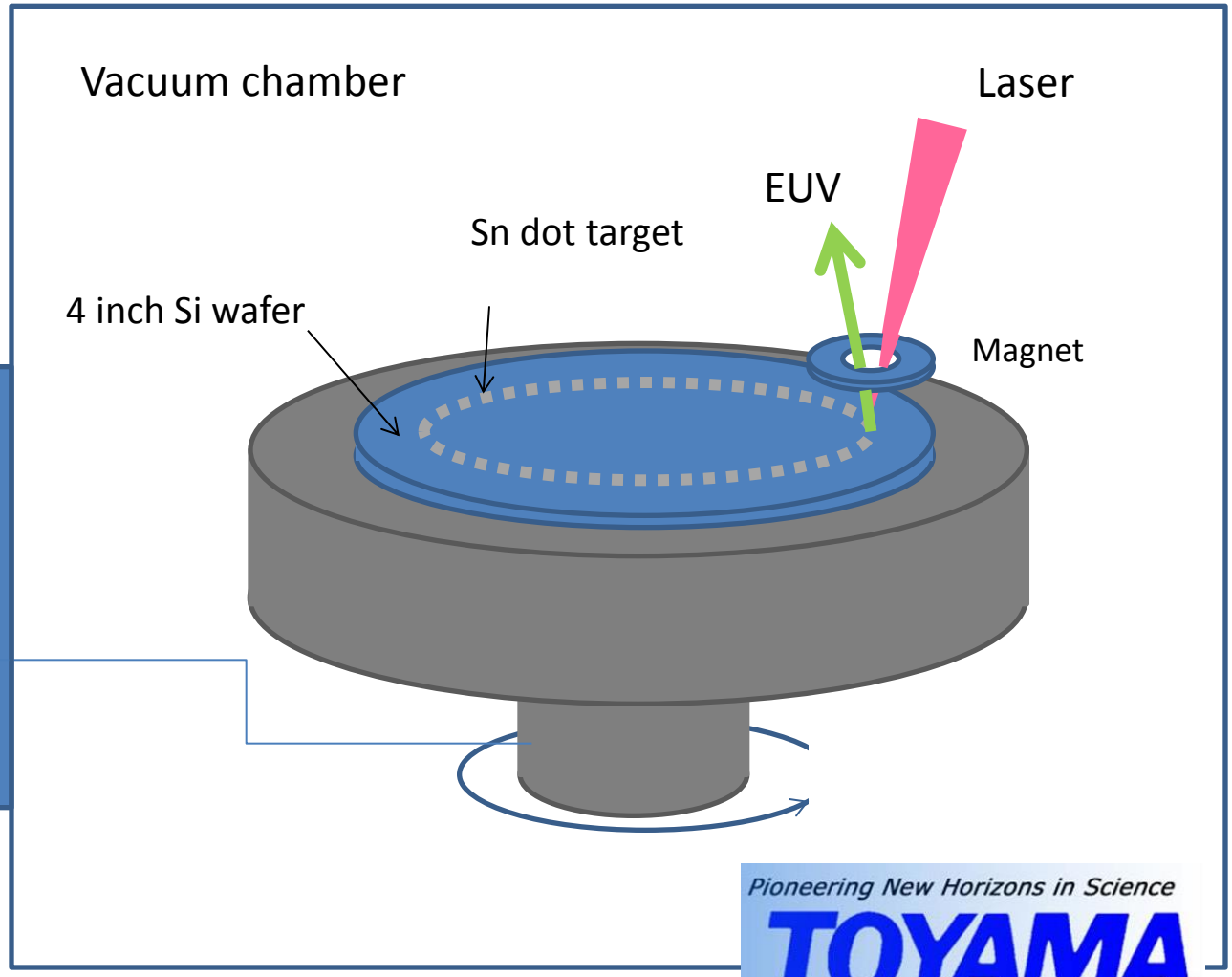
Tin Rotational Target for EUV Metrology Source

hilase
Power of light





Sn dot size: ϕ10 μm
Dot separation: 10 μm
Speed: 4000 rpm
Accuracy: +/- 1 rpm
Pointing stability: +/- 5 μm
Flatness: +/- 5 μm

Pioneering New Horizons in Science
TOYAMA

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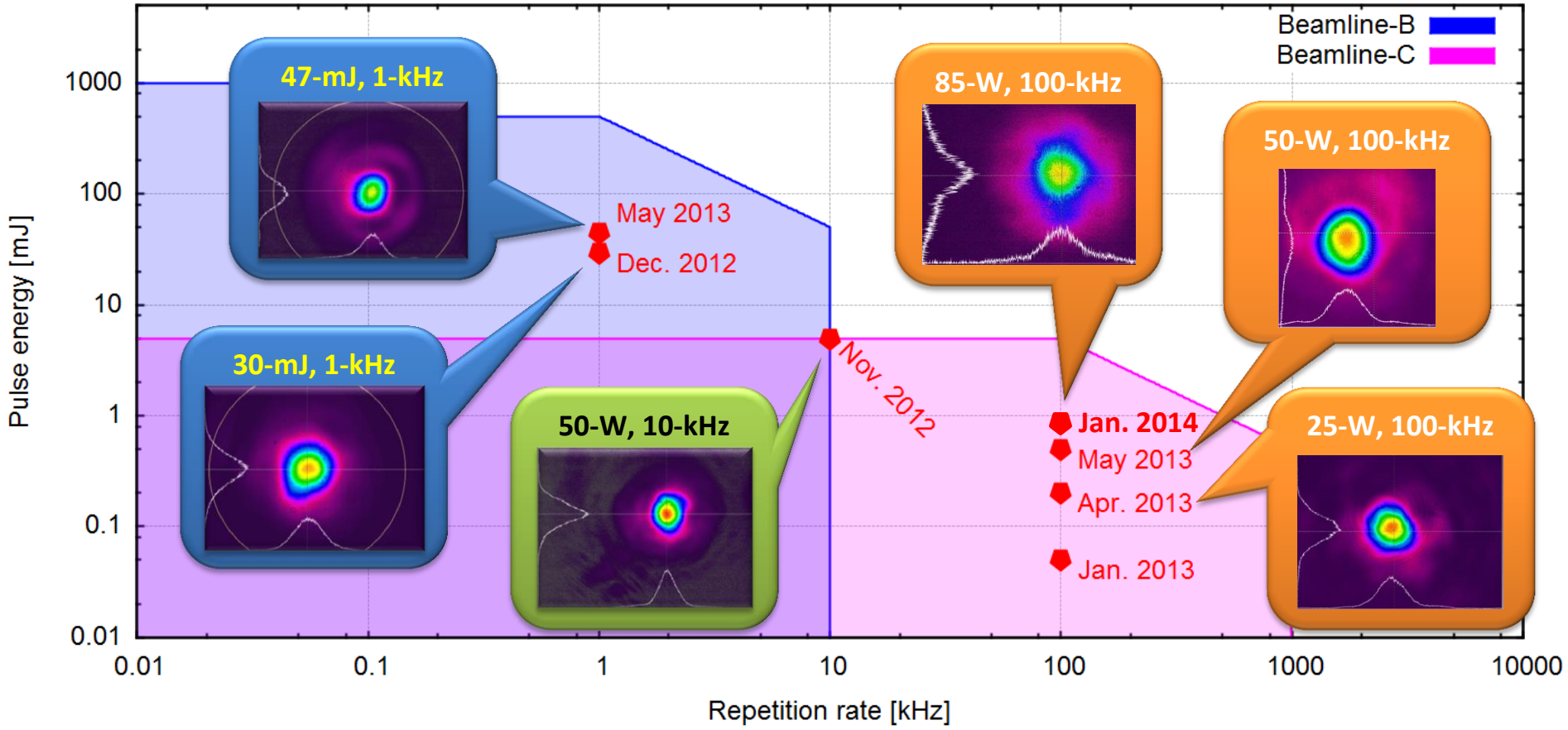
Status of in-house development



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