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Market requirements for short pulse delivery fibers and amplifiers

Lukas Krainer

Management & Company

Company

- 2007 - first product released
- 2008 - acquisition of Advanced Laser Diode Systems GmbH, Berlin
- 2013 - shipped 1000th laser modules
- 2015 - 2000+ ultrafast lasers in 24/7
- 2015 - ISO 9001 + 13485

- Based in Regensdorf ZH, Switzerland & Berlin, Germany
- 1000 m^2 class 1‘000 clean room with class 100 assembly stations
- Operating a world wide distribution and sales network
- Completely independent – no VCs, investors or Business Angels

Founders & owners

Dr. Gabriel Spühler, CTO & Dr. Lukas Krainer, CEO

- PhD & Postdoc at ETH Zürich in ultrafast lasers
- Together 40 years of experience in the field of ultrafast lasers

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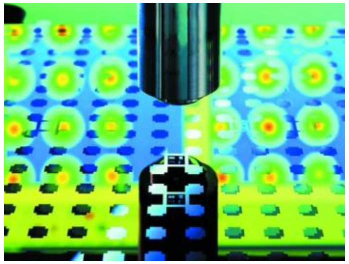
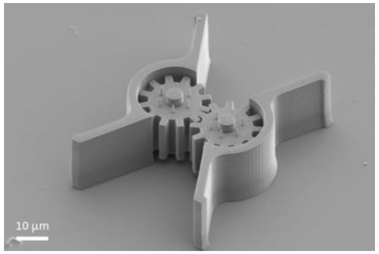
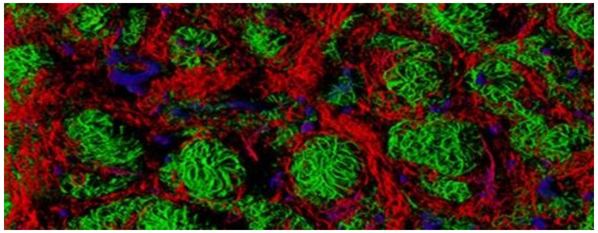
Applications of ultrafast lasers

- Life science: Microscopy, spectroscopy, ...
- Energy: Solar cell manufacturing, ...
- Micromachining: Dicing, glass cutting, stent manufacturing, ...
- Security & Defense: THz systems, radar, ...
- Fundamental science: Timing, astronomy, frequency standards, ...







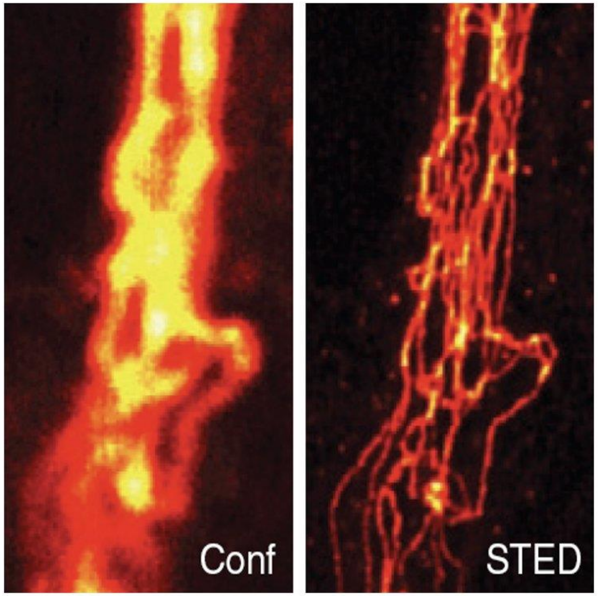
No business relation between Onefive and others can or should be derived from the following presentation.

Super-resolution microscopy

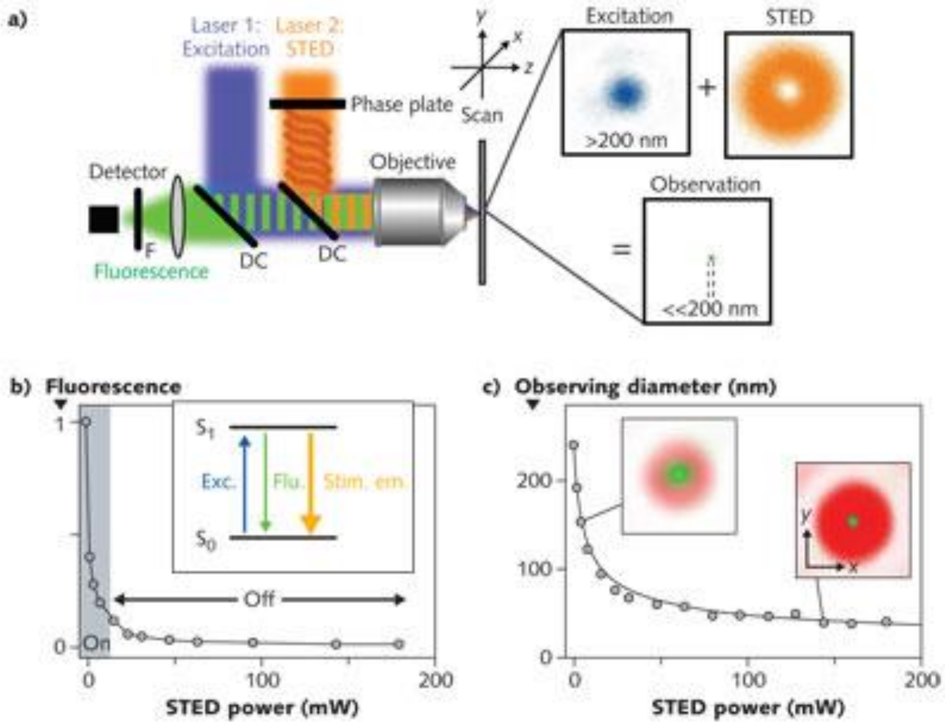
Imaging beyond the diffraction-limit of light

Nobel Prize 2014 in Chemistry to: E. Betzig, S. W. Hell and E. Moerne

S. Hell's technique: STimulated Emission Depletion microscopy (STED)



Resolution down to 20 nm!



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Super-resolution microscopy

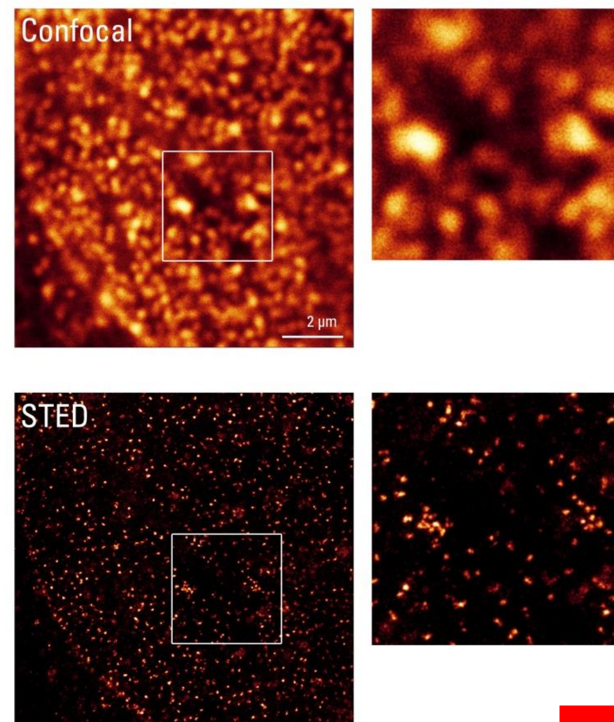
Onefive exclusive supplier with long term agreement

The 775 nm **Katana – 08 HP** installed in the Leica TCS SP8 STED 3X laser rack.

Courtesy of Leica Microsystems

Leica TCS SP8 STED 3X microscope

Resolution enhancement achieved with Leica TCS SP8 STED 3X microscope equipped with the **600 ps, 775 nm, Katana – 08 HP**.



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Super-resolution microscopy

Available wavelengths:

- Infrared: 775, 1064, 1550 nm
- Red: 640 nm
- Orange: 592 nm
- Green: 532 nm
- Blue: 405 nm
- UV: 266, 355 nm

PRISM 2016 AWARDS

Finalist category “Industrial Lasers”

Orange KATANA-06 HP

- Pulse duration: ~500 ps
- Pulse energy: up to 20 µJ
- Average power: up to 20 W
- Repetition rate: up to 120 MHz

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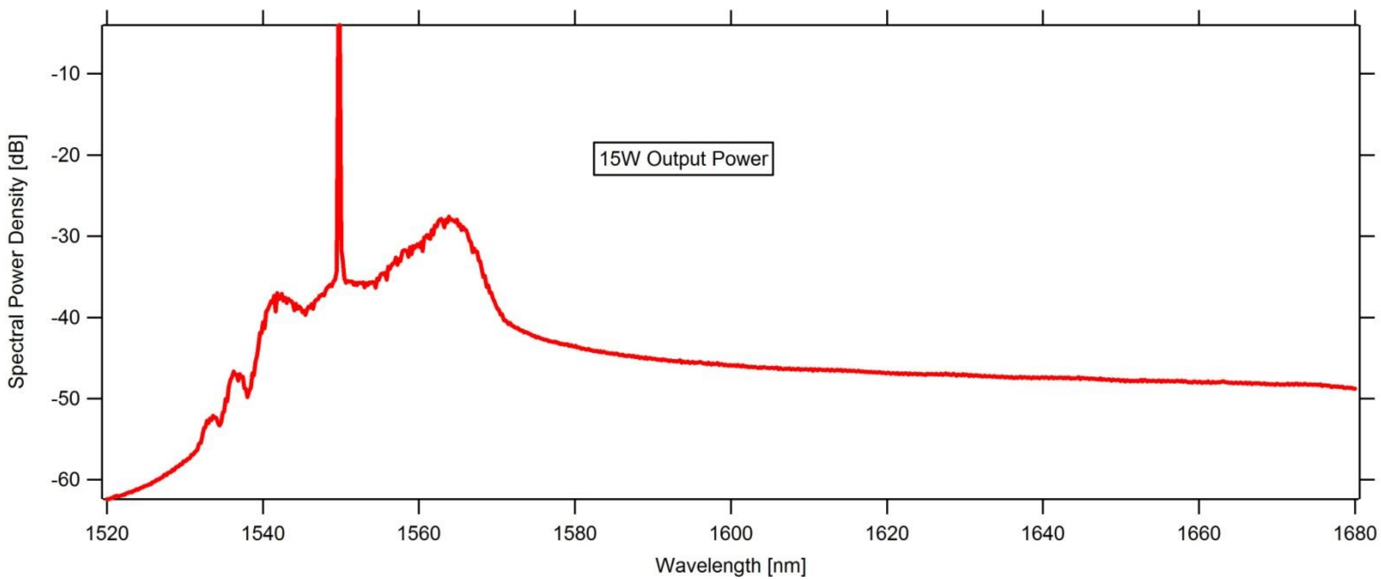
Fiber amplifier issues

For high power (>10W) 775 nm lasers, powerful ps pulsed fiber MOPA configurations are required.

Onset of parasitic effects around 1.0 µm and detrimental spectral broadening (SPM) due to limited LMA fiber (25 µm MFD) availability are present.



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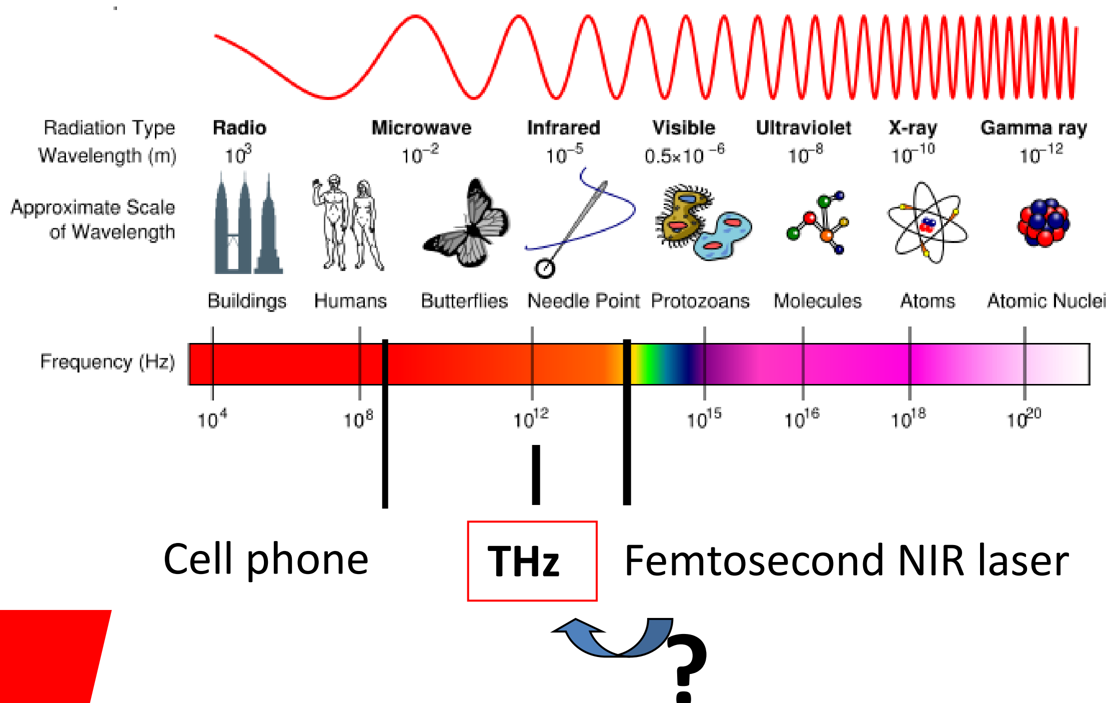
THz imaging



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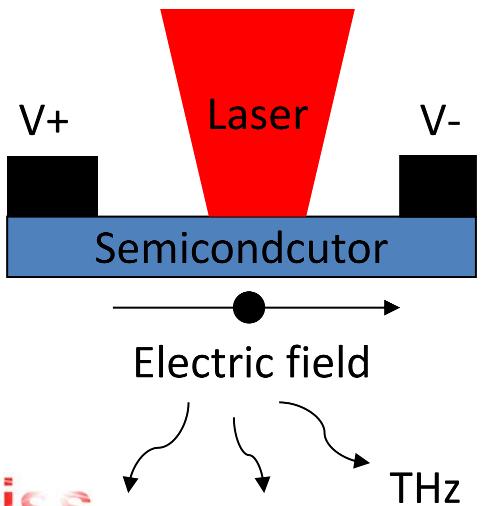
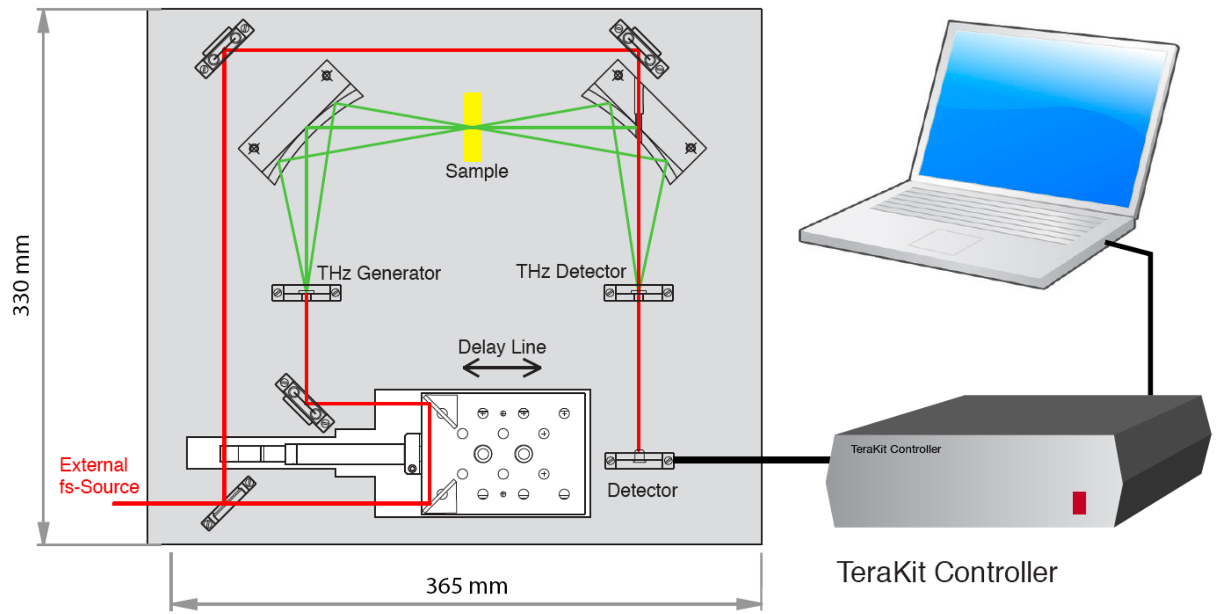


1. Excitation of electrons in a semiconductor by an intense light pulse
2. Free electron acceleration by an electric field (voltage)
3. Accelerated electrons emit THz radiation

THz imaging

Typical system layout

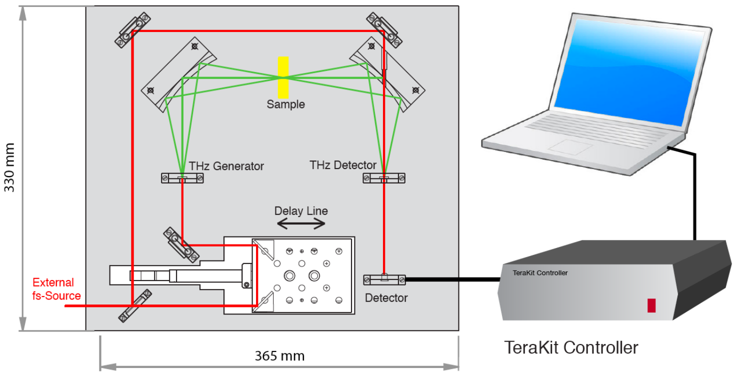


Commercial system provided by Rainbow Photonics

Fiber delivery issues

In harsh environments (like production floor in a paper mill), the laser and the THz system should not be close to each other.

Distances up to 20m required.



Transport of a 100 fs @ 100 MHz pulse train along the optical fibers while maintaining the short pulse duration.

Currently limited to approx 100 mW (1nJ) due to the onset of non linearties in standard telecom fibers. "Wish" would be to have 1550 nm LMA transport fibers in PM with negative and positive dispersion!

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PV thinfilm scribing

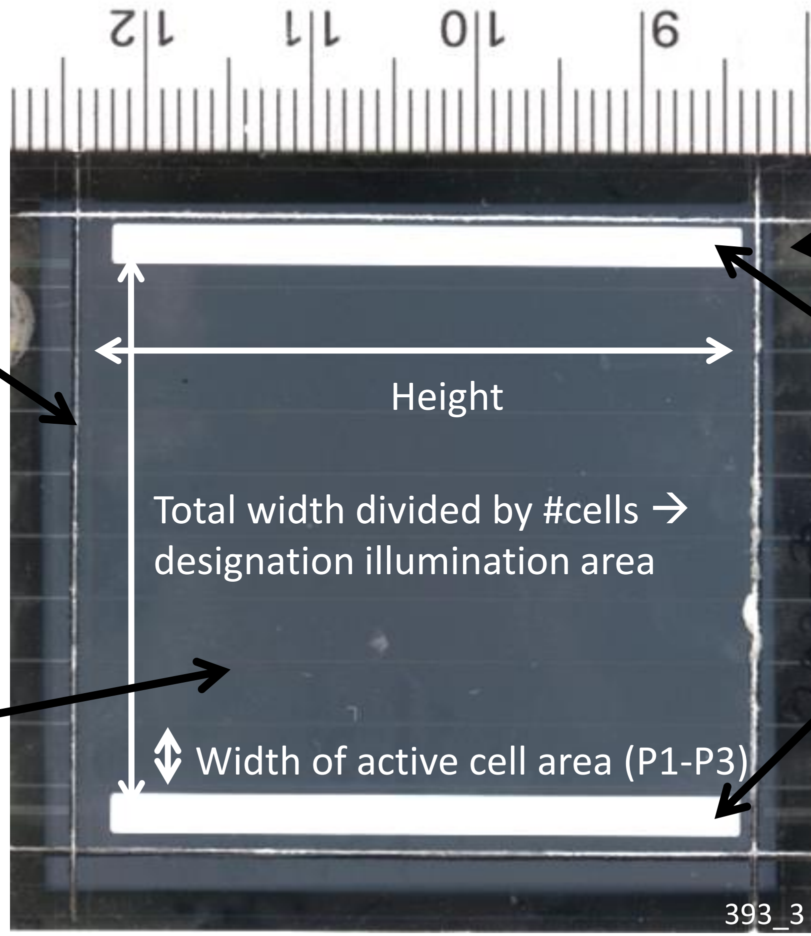
EMPA Materials Science & Technology

Berner Fachhochschule

Functional CIGS solar module

Insulation scribe (P1 & P3)

Mechanical edge dilution



Evaporated Al contact pads

Patterning scribe lines P1 P2 P3 → dead area

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PV thinfilm scribing

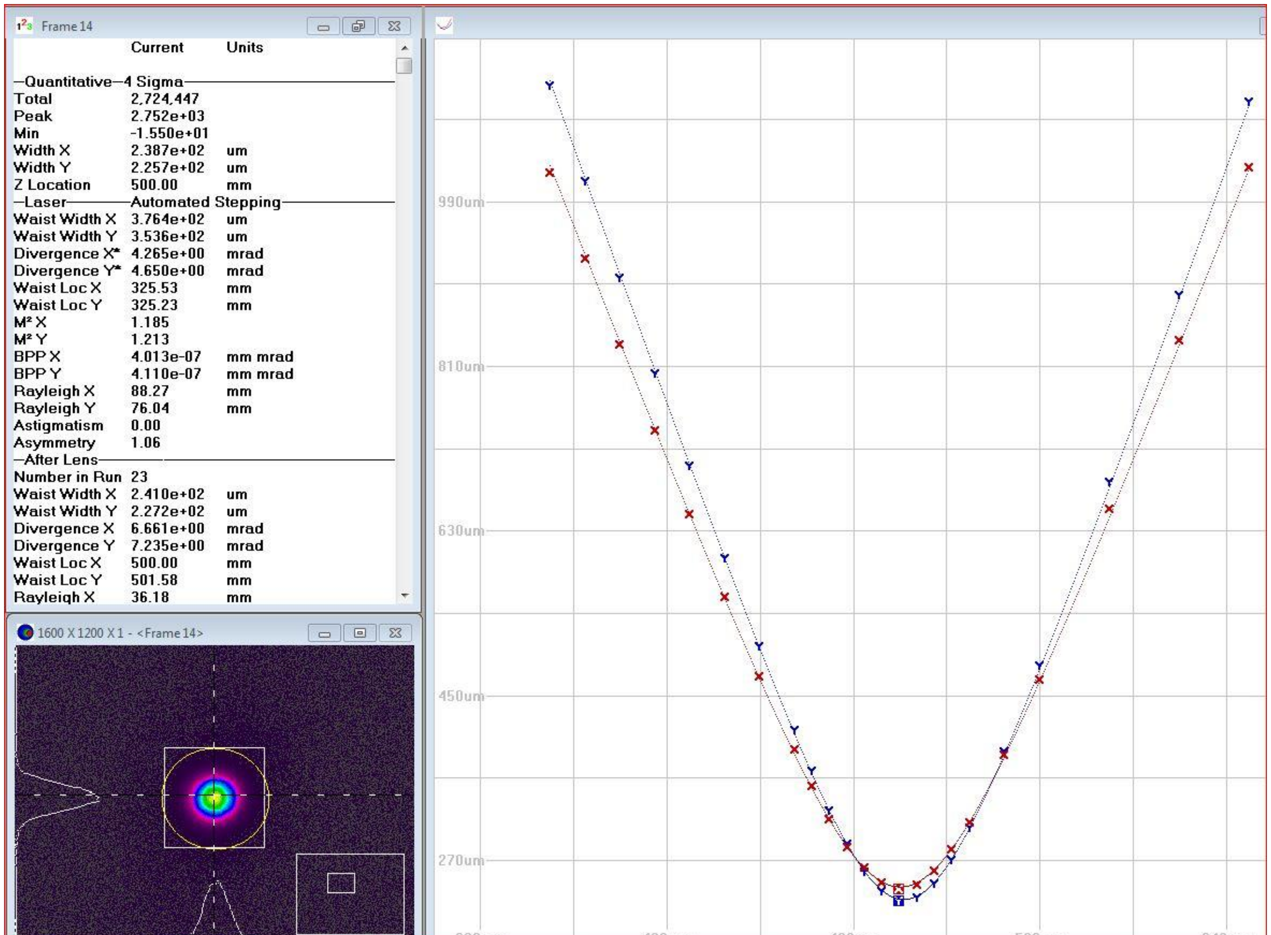
Laser specifications	Katana – 05 HP	Katana – 06 HP	Katana – 08 HP	Katana – 10 HP	Katana – 15 HP
Center wavelength (nm)[1]	**532 nm**	**556 – 660 nm**	**775 nm**	**1064 nm**	**1550 nm**
Pulse Duration[1]	<30 - 1 ns	500 – 1 ns	<30 - 1 ns	<30 - 1 ns	<30 - 1 ns
Avg. output power (up to)[1]	5 W	1 W	8 W	20 W	14 W
Pulse energy (up to)[1]	10 µJ	50 nJ	1 µJ	20 µJ	3 µJ
Peak power (up to)[1]	500 kW	100 W	10 kW	1 MW	100 kW
Pulse repetition rate[1]	pulse-on-demand – 100 MHz				
Spectral bandwidth	> 0.1 nm				
Beam quality	$M^2 < 1.3$, TEM_{00}				
PER	> 23 dB				
Amplitude noise	< 4 % rms (10h)				
Laser output	Collimated free-space				
Environmental					
Warm-up time	< 15 minutes				
Operation temperature	15 °C – 35 °C				
Storage temperature	-20 °C – 65 °C				
On/ Off cycles	> 10000				
Mechanical					
Size laser head	39 X 100 X 162 mm^3				
Weight laser head	1 kg				
Size laser controller	133 X 483 X 400 mm^3 (19"/ 3U rack				
Weight laser controller	7 kg				
Electrical					
Power supply	24VDC/ 9A or 90 – 264 VAC, 47 – 63 Hz				
Power consumption	< 300 W				
Cooling					
Laser system	air cooled				

LMA fibers for ps µJ pulses

Technology standard: 30 µm mode field diameter

10 W, 10 µJ, ps

Good beam quality, power limited!



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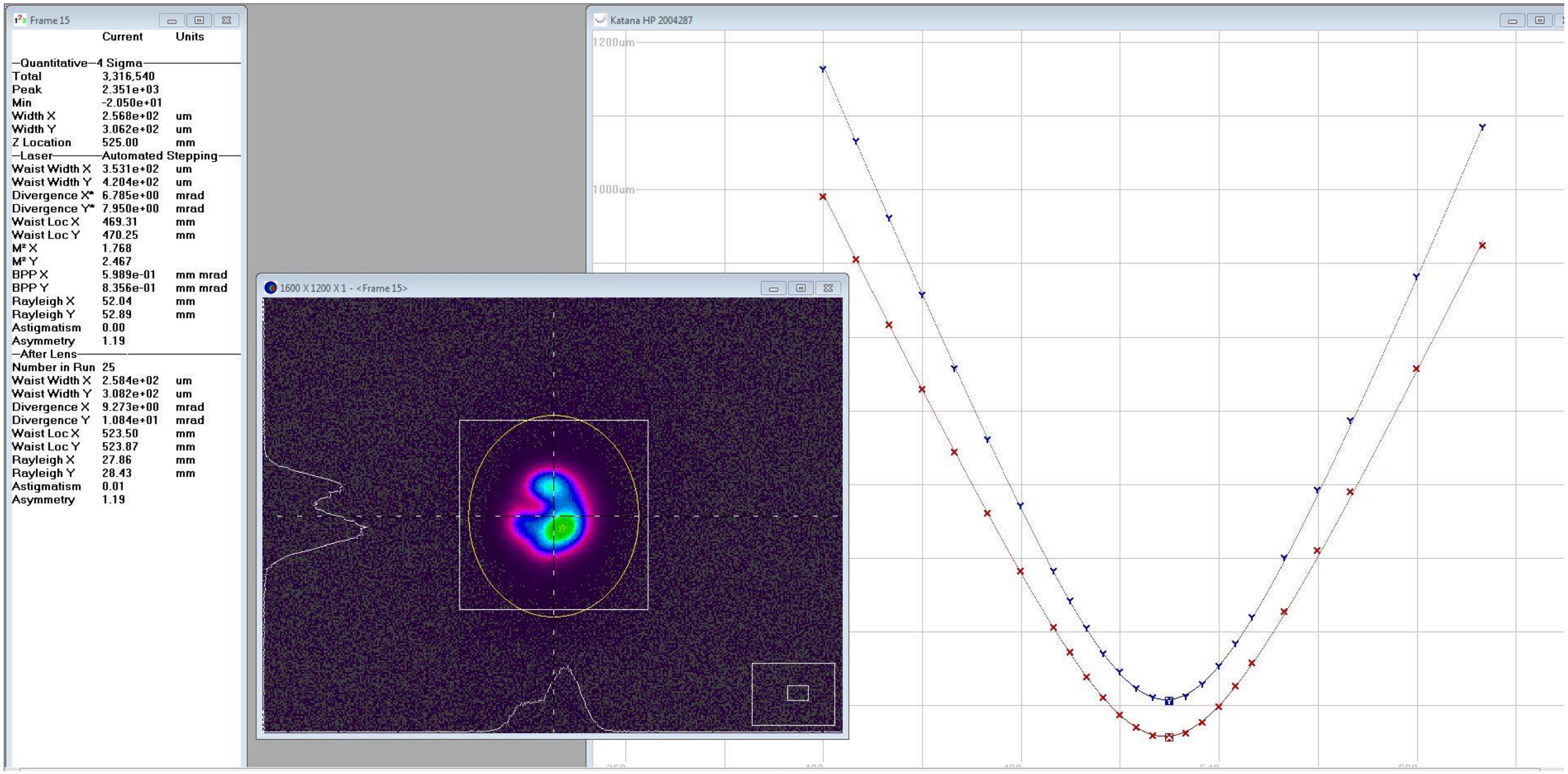
LMA fibers for ps µJ pulses

Next generation LMA fibers: 60 µm mode field diameter

30 W, 30 µJ, ps

Issues with beam quality, not power!



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Femtosecond delivery

Air-cooled all-in-one 400 fs 40 μJ laser

✓ Femtosecond lasers are well developed industrial tools

✓ Typical pulse energies up to 100 μJ with <1ps

✓ Free space delivery

Fiber delivery convenient for most applications.

Kagome/Hollow core type fibers are currently investigated and appear on the market.

Open questions like beam pointing, polarization and pulse distortion remain.

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Conclusions

- Picosecond fiber solutions are well developed to a certain extent.
- Telecom compatible fiber solutions for femtosecond delivery not developed
- Rod-type fiber assemblies are available, but recently no big gain in MFDs
- Limitations in terms of non linearities and manufacturing challenges present.
- Transport fibers for μJ pulse energies are still under development, but initial results show promising routes.
- R&D activities towards uncommon wavelengths (2-μm) are on going.

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Thank you