Working Group 7 / 1st Part

- **WG7 - High brightness power sources: from Laser Technology to beam drivers**

  Topics addressed:
  Needs for laser driven accelerators (laser-plasma ion source, LWFA, IFEL, dielectric laser, ...)
- State-of-the-art of high peak and average power and perspectives
- Laser beam quality, contrast, stability
- **Co-Leader:** Leo Gizzi
  Co-Leader: Barbara Marchetti
  Co-Leader: Rajeev Pattathil

WG7_Parallel

Convener: Leonida Antonio Gizzi (PI), Barbara Marchetti (DESY), Rajeev Pattathil (Central Laser Facility,)

Location: SBIO, Sala Biodola, Hotel Biodola

16:00 **Feedback control of the spatio-temporal properties of high-intensity laser pulses to optimize x-ray and 100 MeV electron generation** *30'*

Speaker: Dan Symes (Central Laser Facility, STFC Rutherford Appleton Laboratory, Didcot, UK)

Material: Slides

16:30 **Phase-space reconstruction of low-emittance electron beams through betatron radiation in a laser-plasma accelerator at FLAME facility** *20'*

Speaker: Alessandro Curcio (LNF)

Material: Slides

16:50 **HDR spatio-temporal intensity mapping by single-shot optical probing** *20'*

Speaker: Mr. Martin Speicher (LMU Munich)

17:10 **Effects of pulse shape and plasma density on laser propagation in laser-driven wakefield accelerators** *20'*

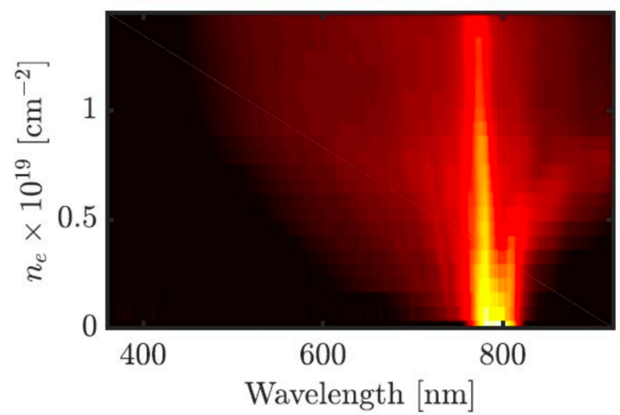
Speaker: Dr. Matthew Streeter (The Cockcroft Institute)

Material: Slides

“Feedback control of the spatio-temporal properties of high-intensity laser pulses to optimize x-ray and 100 MeV electron generation”

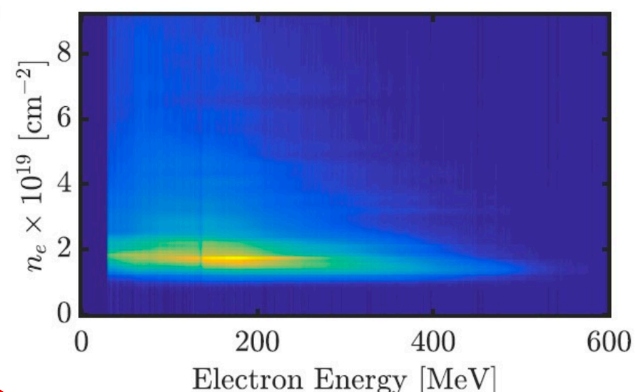
Dan Symes (Central Laser Facility, STFC Rutherford Appleton Laboratory, Didcot, UK)

High rep-rate allows a fine resolution scan of parameter space



Laser spectrum post-plasma as a function of electron density

Electron spectrum as function of electron density



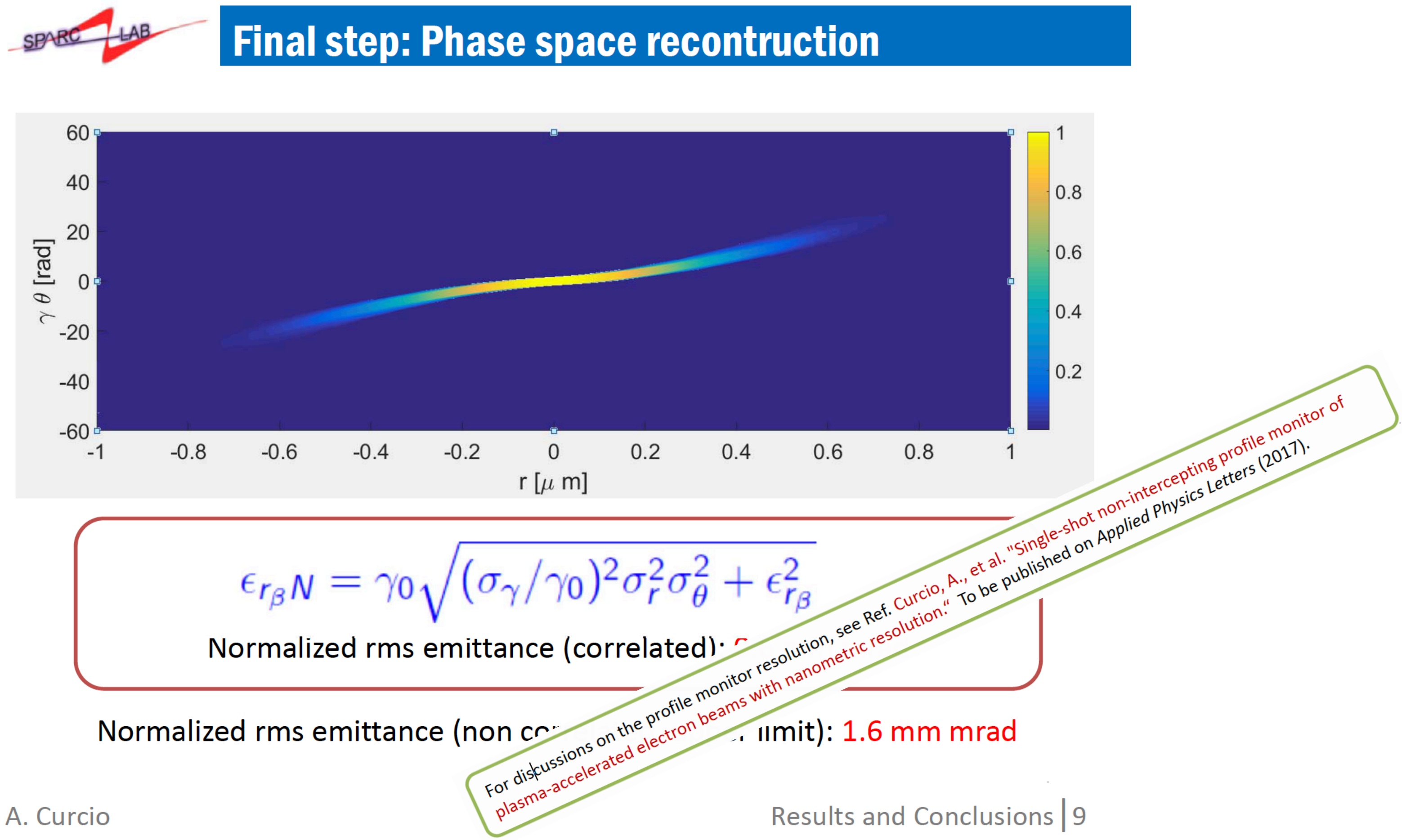
- Each row of data is 50-shot average
- Features that may be missed with coarser scan

Science & Technology Facilities Council

Showing the great potential of feedback loop with rep-rated laser operation √

“Phase-space reconstruction of low-emittance electron beams through betatron radiation in a laser-plasma accelerator at FLAME facility”

Alessandro Curcio (LNF)



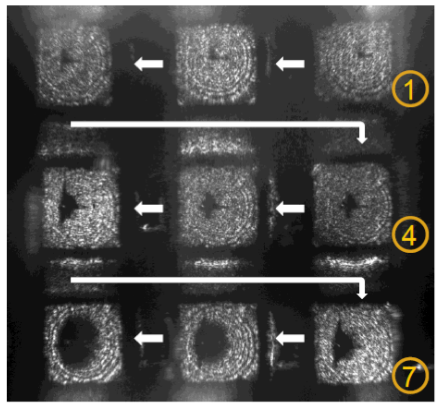
A method for “on-line” monitoring of shot-by-shot variations of LWFA performance √

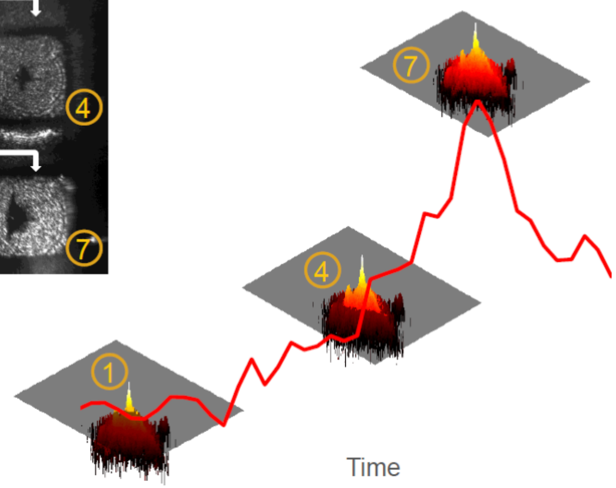
“HDR spatio-temporal intensity mapping by single-shot optical probing”

Martin Speicher (LMU Munich)

Summary – HDR spatio-temporal intensity mapping by single shot optical probing

- Optical probing of the laser-generated plasma on a nm-thin foil with a synchronized, chirped probe pulse
- Image multiplexing provides nine images of the dynamic plasma evolution in a single shot with 200 fs temporal and 25 µm spatial resolution
- New concept to acquire a 2D spatio-temporal intensity distribution of a high power laser on target at full shot
- Future: Powerfull tool to analyse spatio-temporal laser plasma conditions on target (e.g. with implemented plasma mirror)

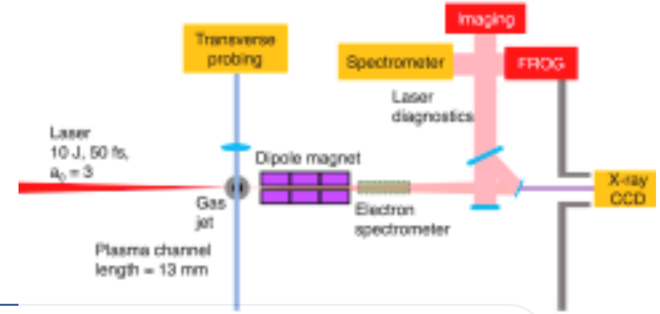


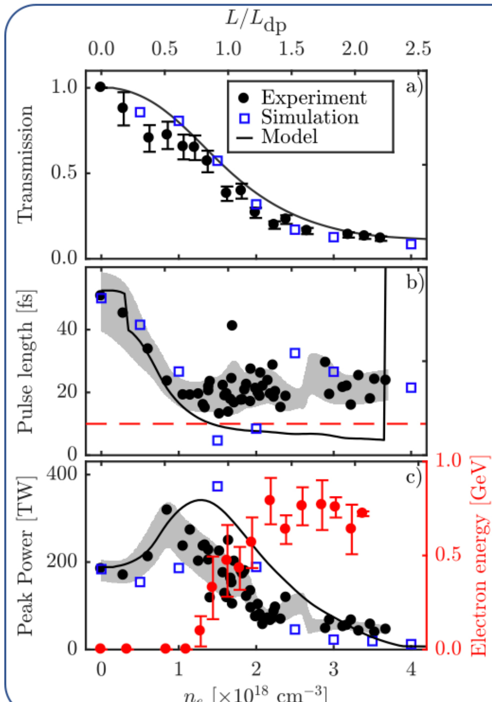


Technique to extract details of laser pulse temporal evolution ON TARGET √

“Effects of pulse shape and plasma density on laser propagation in laser-driven wakefield accelerators”

Matthew Streeter (The Cockcroft Institute)





Diagnostic of laser properties after driving 0.8 GeV plasma wakefield accelerator provide **detailed measurements of pump-depletion and pulse compression** in the highly non-linear regime.

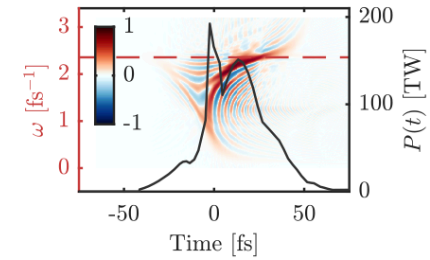
This reveals **power amplification** that precedes self-injection

New model developed to describe laser pulse evolution

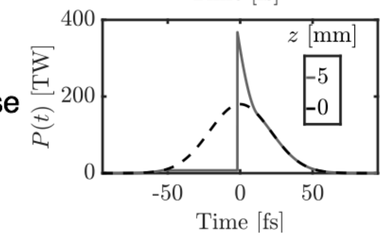
Sufficiently redshifted photons,

$$\omega < \omega_0/\sqrt(3)$$

drift backwards through the pulse, due to group velocity dispersion.



Redshifted photons contribute to the laser power behind the pulse front.



Pre-injection pulse evolution length (when maximum power is reached) is dependent on initial pulse shape.

For a gaussian laser pulse:

$$L_{\rm evol} \approx \sigma_t c \left(\frac{2}{3}\frac{{\omega_0}^2}{{\omega_p}^2}\right)\sqrt{\frac{1}{2}\ln\left(\frac{P_0}{P_c}\right)}$$

$$L_{\rm dp} \approx 2L_{\rm evol}$$

M.J.V. Streeter, S. Kneip, M.S. Bloom, R.A. Bendoyro, O. Chekhlov, A.E. Dangor, A. Döpp, C.J. Hooker, J. Holloway, J. Jiang, N.C. Lopes, H. Nakamura, C.A.J. Palmer, P.P. Rajeev, J. Schreiber, D.R. Symes, S.P.D. Mangles and Z. Najmudin

Direct detection of role of laser/plasma properties on LWFA √

Working Group 7 / 2nd Part

- **WG7 - High brightness power sources: from Laser Technology to beam drivers**

  Topics addressed:
  Needs for laser driven accelerators (laser-plasma ion source, LWFA, IFEL, dielectric laser, ...)
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WG7_Parallel

Convener: Leonida Antonio Gizzi (PI), Barbara Marchetti (DESY), Rajeev Pattathil (Central Laser Facility,)

Location: SBIO, Sala Biodola, Hotel Biodola

18:00 **Laser technology for k-BELLA and beyond** *30'*

Speaker: Dr. Wim Leemans (Lawrence Berkeley National Laboratory)

18:30 **The FLAME laser at SPARC_LAB** *15'*

Speaker: Maria Pia Anania (LNF)

Material: Slides

18:45 **Control and propagation effects of the wavefront quality for a high-power laser system** *15'*

Speaker: Mr. Vincent Leroux (ELI Beamlines)

19:00 **Laser beam circulator for high brightness Inverse Compton Scattering Sources** *15'*

Speakers: Dr. Kevin Cassou (Laboratoire de l'Accélérateur Linéaire), Mr. Cheikh Fall Ndiaye (LAL), Dr. Aurelien Martens (LAL/IN2P3/CNRS)

19:15 **Ten Meter Laser Propagation with Resonance Enhanced Ionization of Rubidium for Plasma Generation at AWAKE** *15'*

Speaker: Dr. Joshua Moody (Max Planck Institute for Physics)

Material: Slides

“Laser technology for k-BELLA and beyond”

Wim Leemans (Lawrence Berkeley National Laboratory)

A comprehensive and inspiring view of future development of high average power CPA lasers √

“HIGH EFFICIENCY, DIODE PUMPED PETAWATT LASERS FOR THE NEXT GENERATION PARTICLE ACCELERATORS AND SECONDARY SOURCES”

Constantin Haefner, Craig Siders, Andy Bayramian, David Alessi, Kyle Chestnut, Al Erlandson, Eyal Feigenbaum, Tom Galvin, Paul Leisher, Emily Link, Dan Mason, Bill Molander, Paul Rosso, Margareta Rehak, Kathleen Schaffers, Tom Spinka

Lawrence Livermore National Laboratory

- We have developed a conceptual design for a single-aperture, 300 kW Thulium:YLF Petawatt-class laser **“BAT”** consistent with requirements for laser wakefield accelerators
- The underlying technology is a modest extension of established LLNL gas-cooling and rep rated Petawatt technologies
- BAT makes use of a highly simplified laser architecture, multi-pulse extraction of CW-diode pumped Tm:YLF and thus providing good wall-plug-efficiency
- We have developed a list of system TRLs and challenges that will inform the strategic plan for R&D and RTP efforts

System	Type	TRL Estimate	Integration Challenge	delivery horizon	E (J)	t (fs)	P_{av} (kW)	P_{peak}(PW)
HAPLS	DPSSL+TiS	7	Low	today	30	<30	0.3	1
SHARC	DP CPA Nd:Glass	6	Low	3yrs	150	150	1.5	1
Mini-BAT	DP CPA Tm:YLF	3-4	Medium	3-5yrs	3	40 or 100	3	.075
BAT	DP CPA Tm:YLF	3	Medium	5-7yrs	30	40 or 100	300	.75

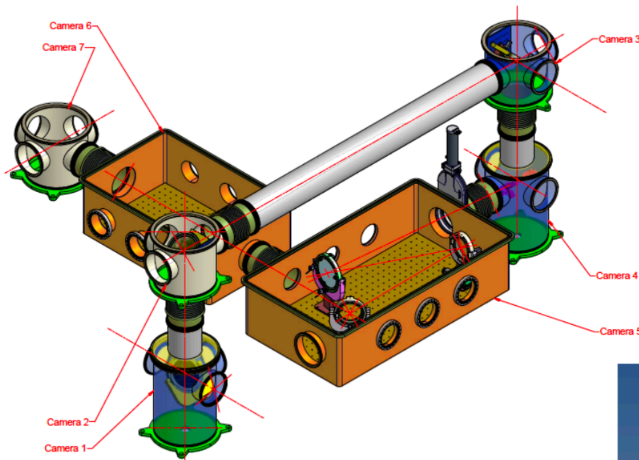
PAVING THE WAY TO 100 kW scale average power multi PW systems √

“The FLAME laser at SPARC_LAB”

Maria Pia Anania (LNF)

SPARC LAB

External injection



Design of the vacuum chamber for the laser transport.

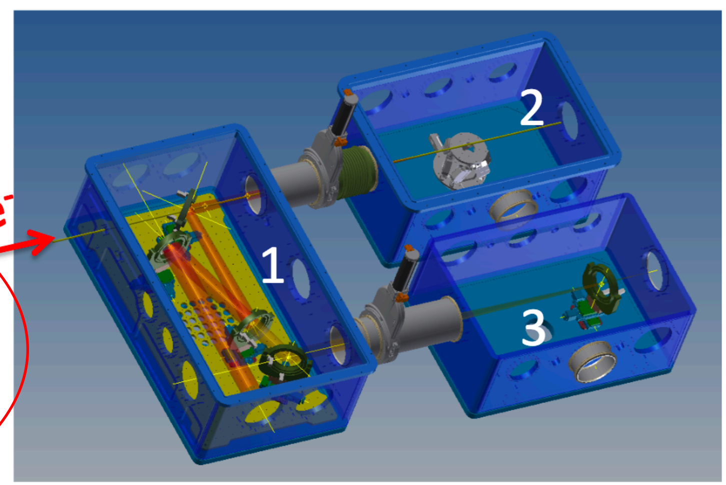
1st chamber is for mirrors and 3 m focal length off-axis parabola,

2nd chamber is for interaction and 3rd chamber is for diagnostics.

Movements of the capillary (filled with H2) will be made with hexapod.

Synchronization: needs to be at the fs level.

e^-



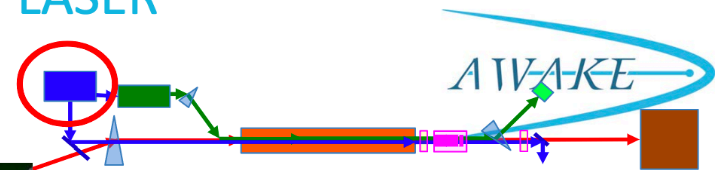
Unique full range of LINAC/Laser based science cases setting pointing and sync challenges √

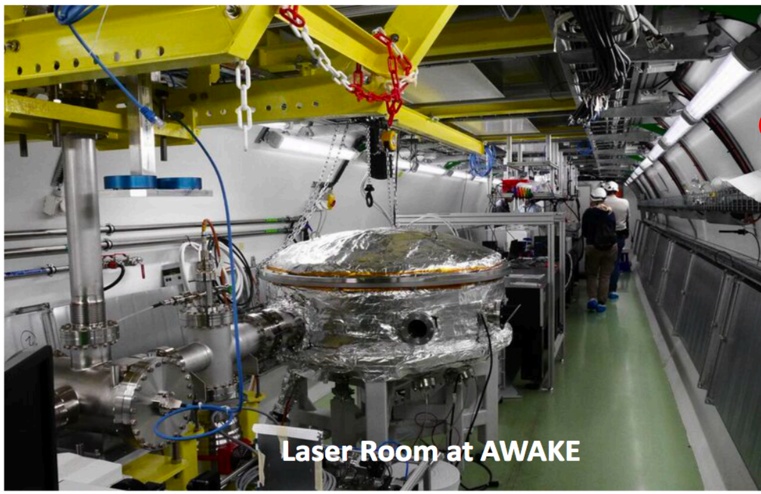
"Ten Meter Laser Propagation with Resonance Enhanced Ionization of Rubidium for Plasma Generation at AWAKE"

Joshua Moody (Max Planck Institute for Physics)

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

TW LASER





Laser System	
Laser type	Er:Fiber/ OscillatorTi:Sapphire
Pulse wavelength	λ_0 = 780 nm
Pulse length	120 fs FWHM
Pulse energy (after compressor)	**450 mJ**
Laser power	**4.5 TW**
Focused laser size	$\sigma_{x,y}$ **= 1 mm**
Rayleigh length Z_R	~3.5 m
Energy stability	±1.5% r.m.s.
Repetition rate	10 Hz

- Fiber laser chosen for stability on long runs
- Laser BW is only 15nm with peak spectrum at 780nm
- Several Rb lines within spectrum

MAX-PLANCK-GESELLSCHAFT

Diagnostic (ionizing and self-mod seeding) laser with 4.5 TW fiber technology for stability √

“Wavefront and focal spot quality for a high-power laser system: ANGUS”

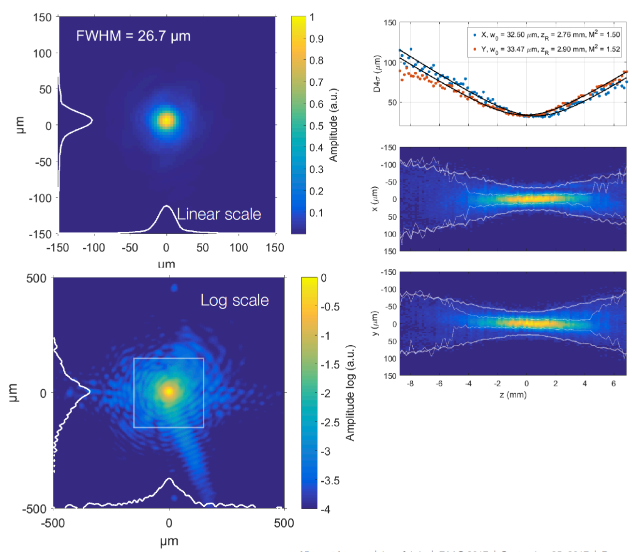
Vincent Leroux (ELI Beamlines)
CFEL, ELI-Beamlines
vincent.leroux@desy.de
lux.cfel.de
Contributions: M. Schnepp, S. Jolly, A. R. Maier

> Focal spot optimisation with standard adaptive optics loop

> Good focal spot and evolution through the focus

> Looks worse in log scale

> Increases damage rate of the capillary target

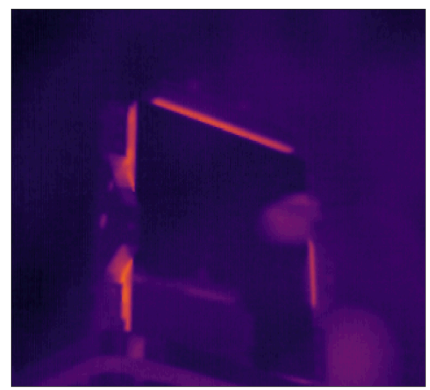


> Started to systematically investigate the influence of high average power on grating compressor

> Diagnostics includes IR camera to observe the substrate temperature

> Ongoing analysis

> See also laser-plasma.de

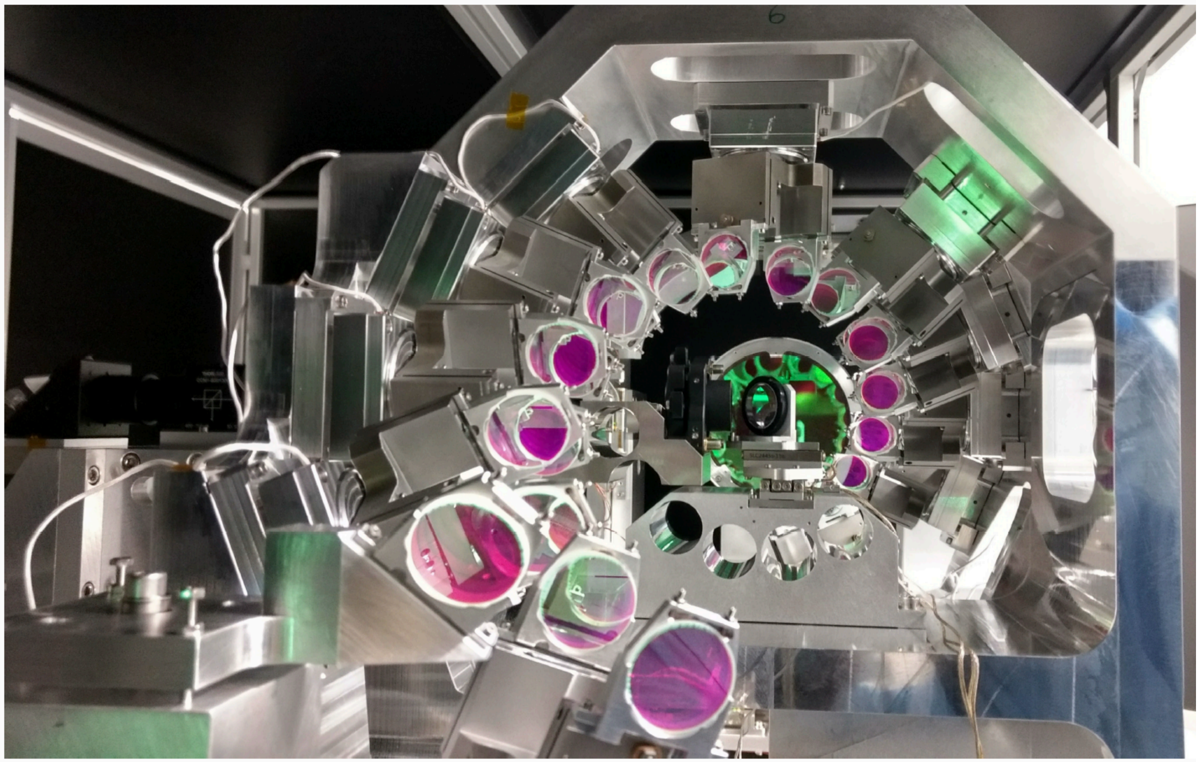


Great effort in detailed characterization of actual laser specs at interaction point and first investigations of effects of re-rated operation on transport line √

“Laser beam circulator for high brightness Inverse Compton Scattering Sources”

Dr. Kevin Cassou (Laboratoire de l'Accélérateur Linéaire), Mr. Cheikh Fall Ndiaye (LAL), Dr. Aurelien Martens (LAL/IN2P3/CNRS)

view of the laser beam circulator prototype:



Towards successful implementation of self-alignment algorithms for alignment at interaction point

Summary of WG7

High brightness power sources: from Laser Technology to beam drivers

- WG7 was a great opportunity to learn about leading edge science&tech of laser characterization and control and imagine future directions for laser drivers for particle acceleration in plasmas
- **Highly recommended WG for future EAAC conferences: will likely grow significantly**
- Thanks to all contributors (especially those who uploaded their slides in time ☺)