PHELIX: Status and Prospects

Picture: F. Nürnberg

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4th EMMI workshop on Plasma Physics with Intense Heavy Ion and Laser Beams
May 2-4, 2011, Darmstadt, Germany

summary

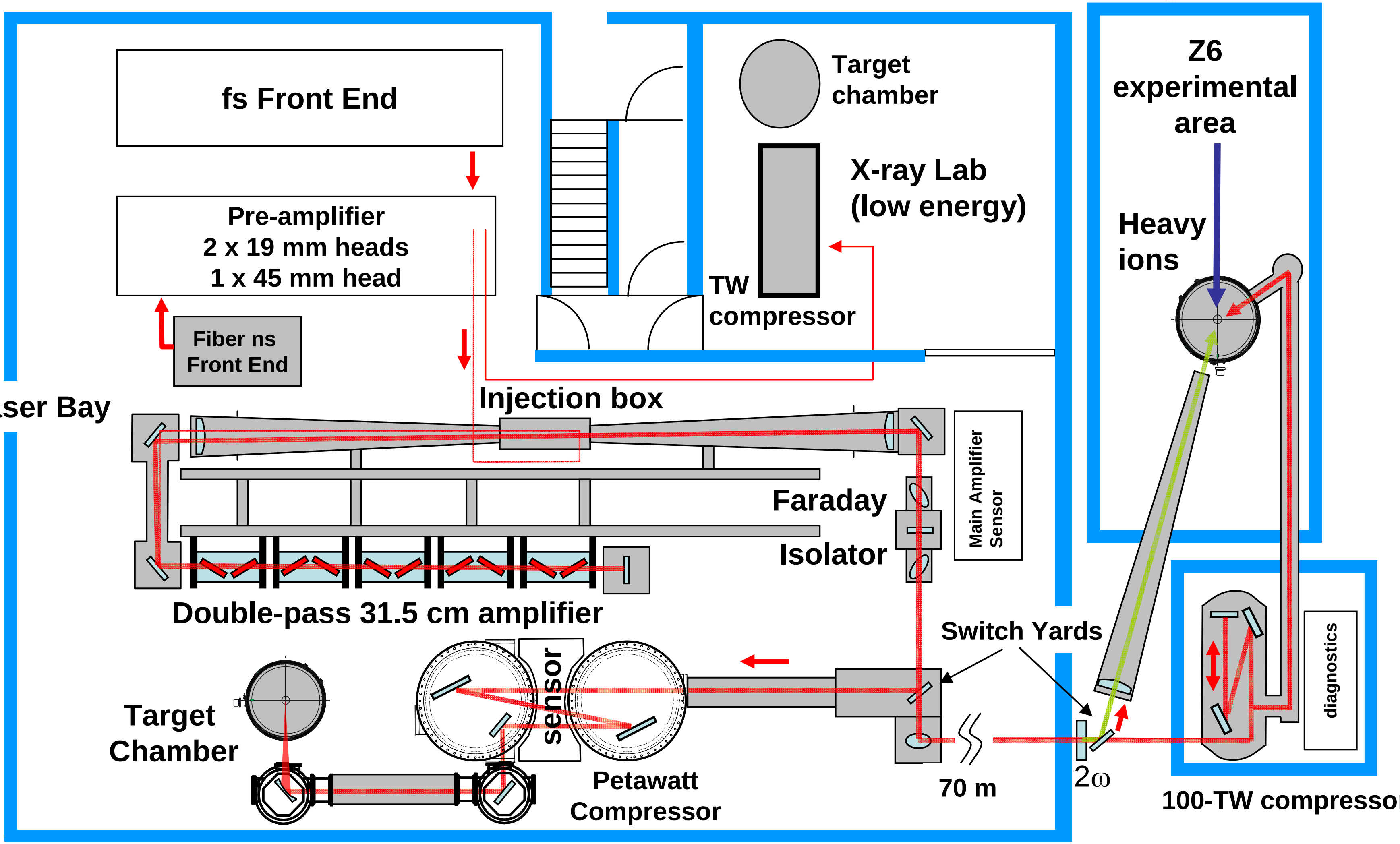
PHELIX has gained a lot of momentum in the last years

- **Overview of the Facility**
  - **Technical overview – PHELIX in 2011**
  - **Operation aspects – towards more service for the users**

- **Significant improvements have been recently done to the facility:**
  - **A pump-probe laser setup has been implemented at PHELIX**
  - **A new 100 TW beamline has been added at Z6**
  - **Frequency conversion of the long pulse with interesting first results**

- **Outlook on improvements to come**
  - **High Contrast short pulses**
  - **Upgrade of the Petawatt target area**
  - **High shot rate**

Schematics of PHELIX – May 2011



PHELIX beam-time offer reaches 26 weeks

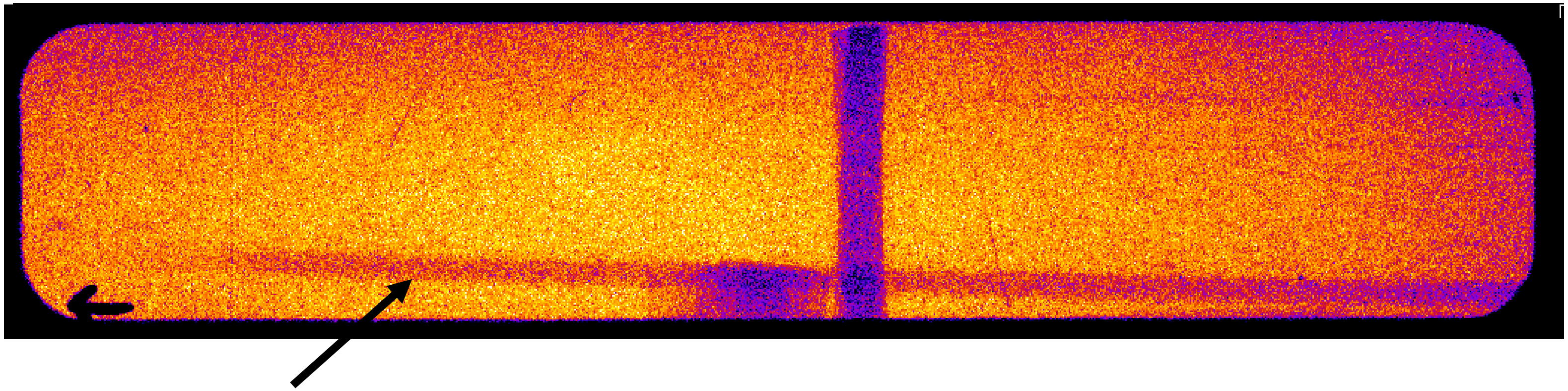
- **PHELIX is dedicated to external users 50% of the time**

- **In 2011, we plan to extend the external beam-time offer by 30% in order to answer to the high demand for beamtime**

- **We try to optimize operation to offer a better service:**
  - **Target area dedicated personnel for the laser-bay and Z6**
  - **Development of a user-accessible shot database**
  - **Financial and technical support via internal resources and/or third party funding**

For more details about the present capabilities of PHELIX go to our website: http://www.gsi.de/forschung/pp/index_e.html

Recent improvements



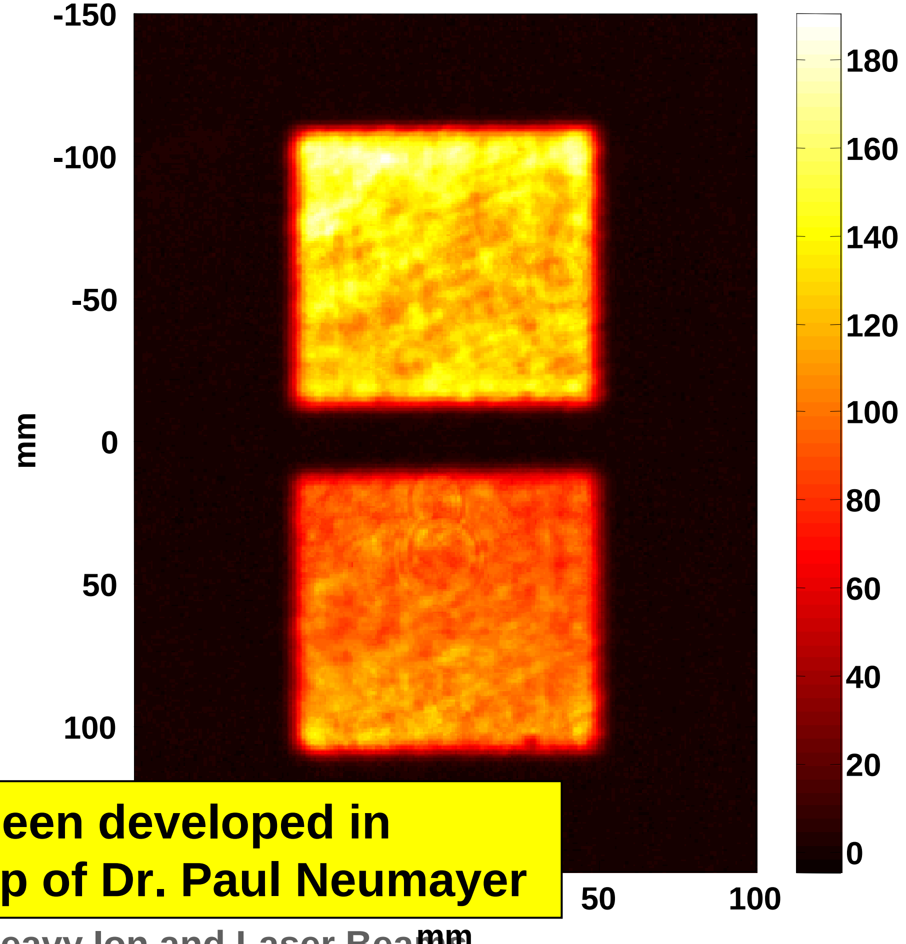
50 µm Ti wire, cold, copper Kα backlighting with 3 µm Cu foil;
resolution: transversal ~ 20 µm, longitudinal ~ 60 µm

Pump-probe laser experiment capabilities were extended

- **Since 2007 a collinear setup with two-pulse capability applicable to X-ray laser setup has been developed**

- **Recently we added two sub-apertures to PHELIX to amplify two distinct beams:**
  - One can choose independently the nature of the beams (short or long pulses)
  - Each beam operates at a level higher than 100 TW
  - Both beams can be independently

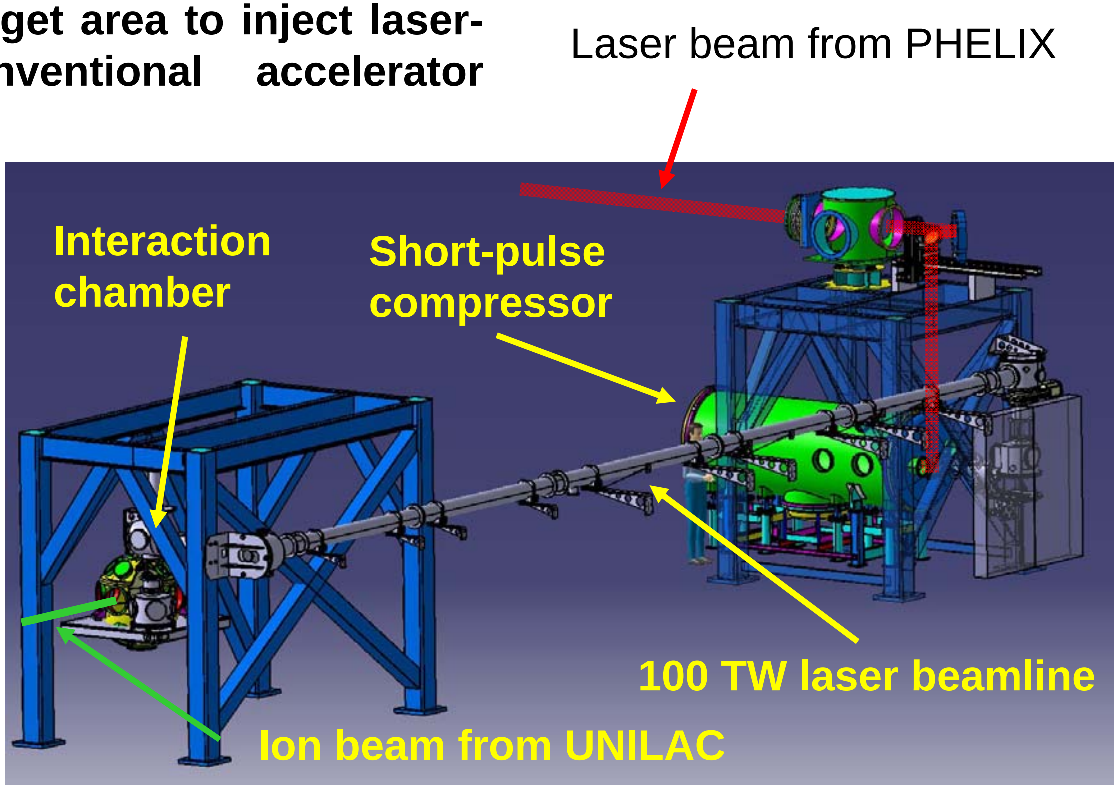
Near field image recorded at the end of chain sensor



The two-beam option has been developed in collaboration with the EMMI group of Dr. Paul Neumayer

A new 100 TW beamline has been added at Z6

- **GSI together with TU-Darmstadt and HI-Jena, have built a short-pulse beamline to the Z6 target area to inject laser-accelerated particles into conventional accelerator structures: 100 TW project**



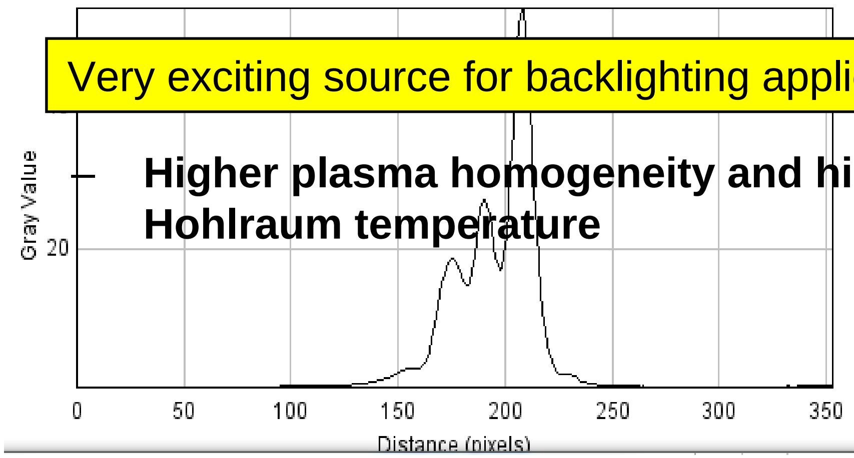
- **The 100 TW serves primarily the LIGHT collaboration but it is available for other users**
  - **The beamline has been commissioned in January 2011 at a ~ 10 J energy level**
  - **We plan to upgrade the energy to 20 J to 30 J in May**
  - **In the medium term, 50 J should be available**

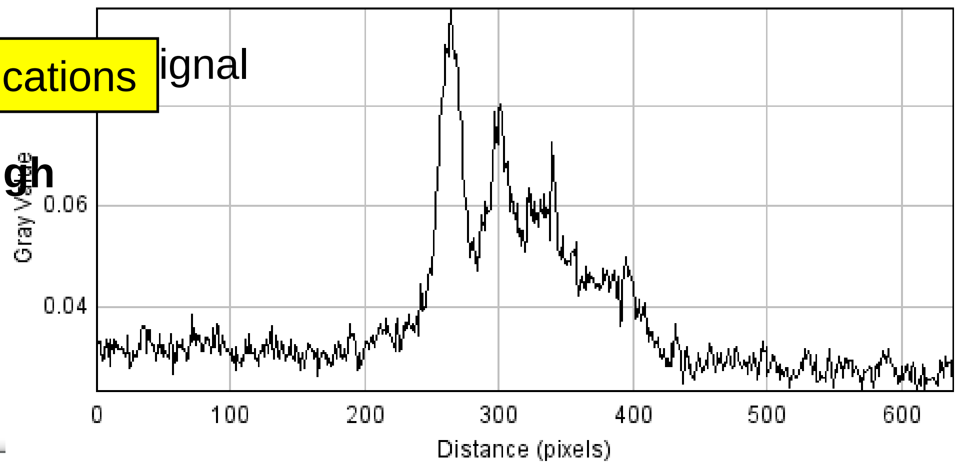
The 100 TW beamline has already been used to successfully accelerate protons to an energy of 10 MeV

The frequency conversion at the experimental area Z6

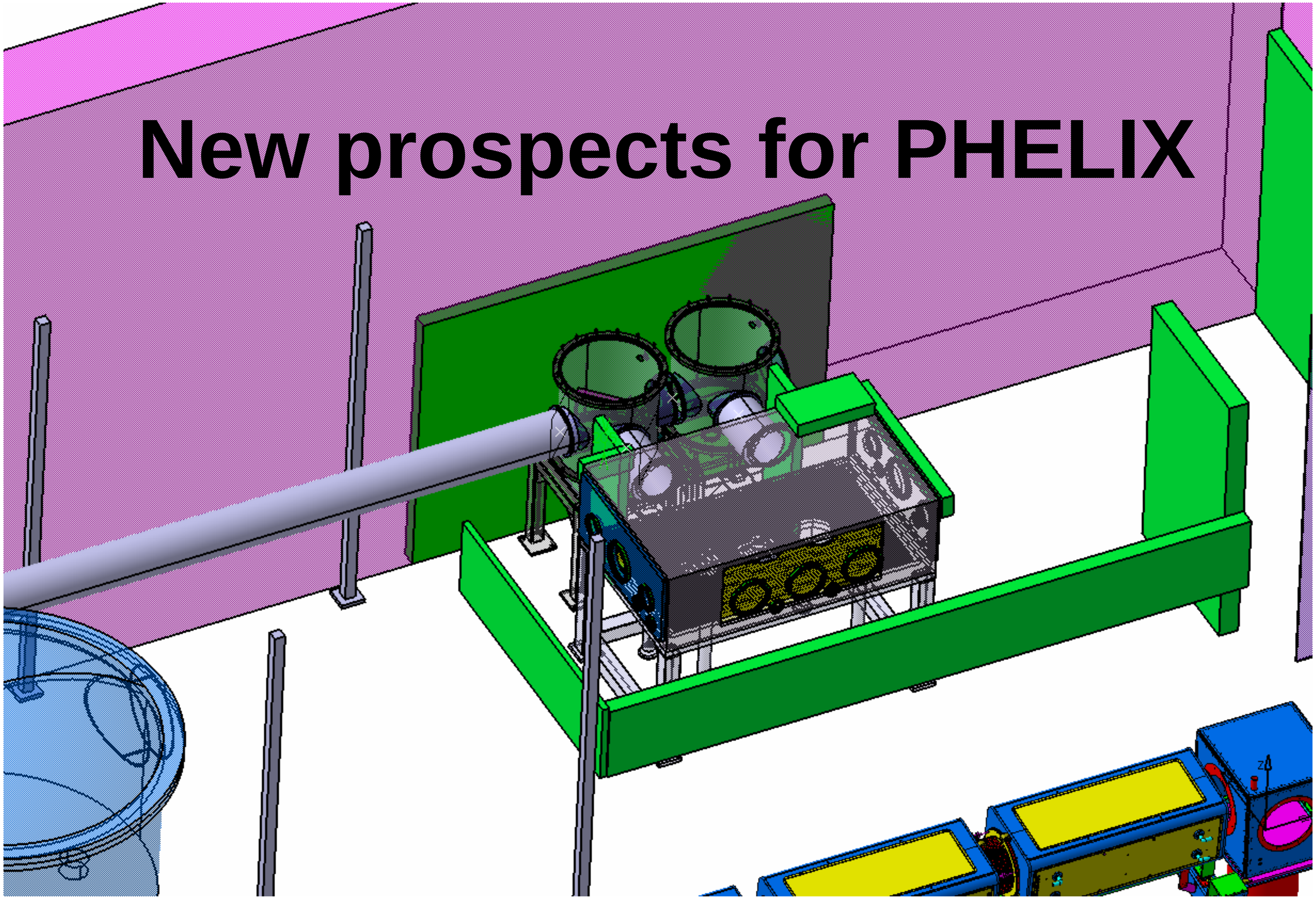
- Frequency conversion allows for better plasma generation and avoids the problem of back-reflected light
- The maximum available 2ω energy is 175 J in 1 ns at the target area, with 57% conversion efficiency
- Very good results have been observed so far
  - 0.5% conversion efficiency into Heα X-ray radiation, ~10^{15} photons/shot
  - Higher plasma homogeneity and high Hohlraum temperature

Very exciting source for backlighting applications





New prospects for PHELIX

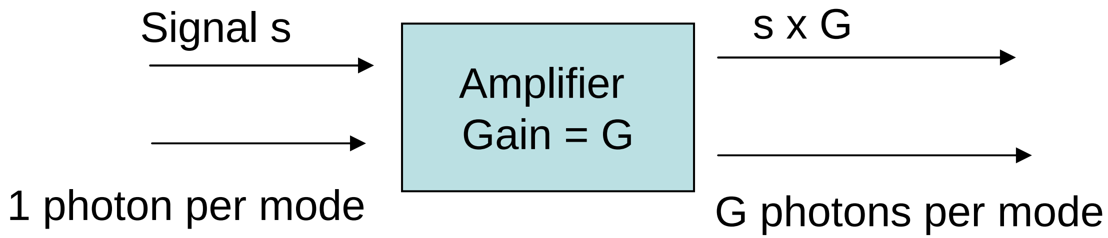


We are preparing for new improvements

- High temporal contrast
  - Pre-pulse and amplification stage decoupling – LAPC project: completed in 2011
  - uOPA project: a high contrast front end at PHELIX developed in collaboration with the HI-Jena
    - Most procurements are done and the pump laser is near completion
- Increased power and on-target intensity
  - UPTA: 300 J, 500 fs pulses on target with pump/probe capability and tight focus
- Higher shot rate
  - Long term project but a first step was done in 2010

Ultrafast Optical Parametric Amplification is a pedestal-free amplification method

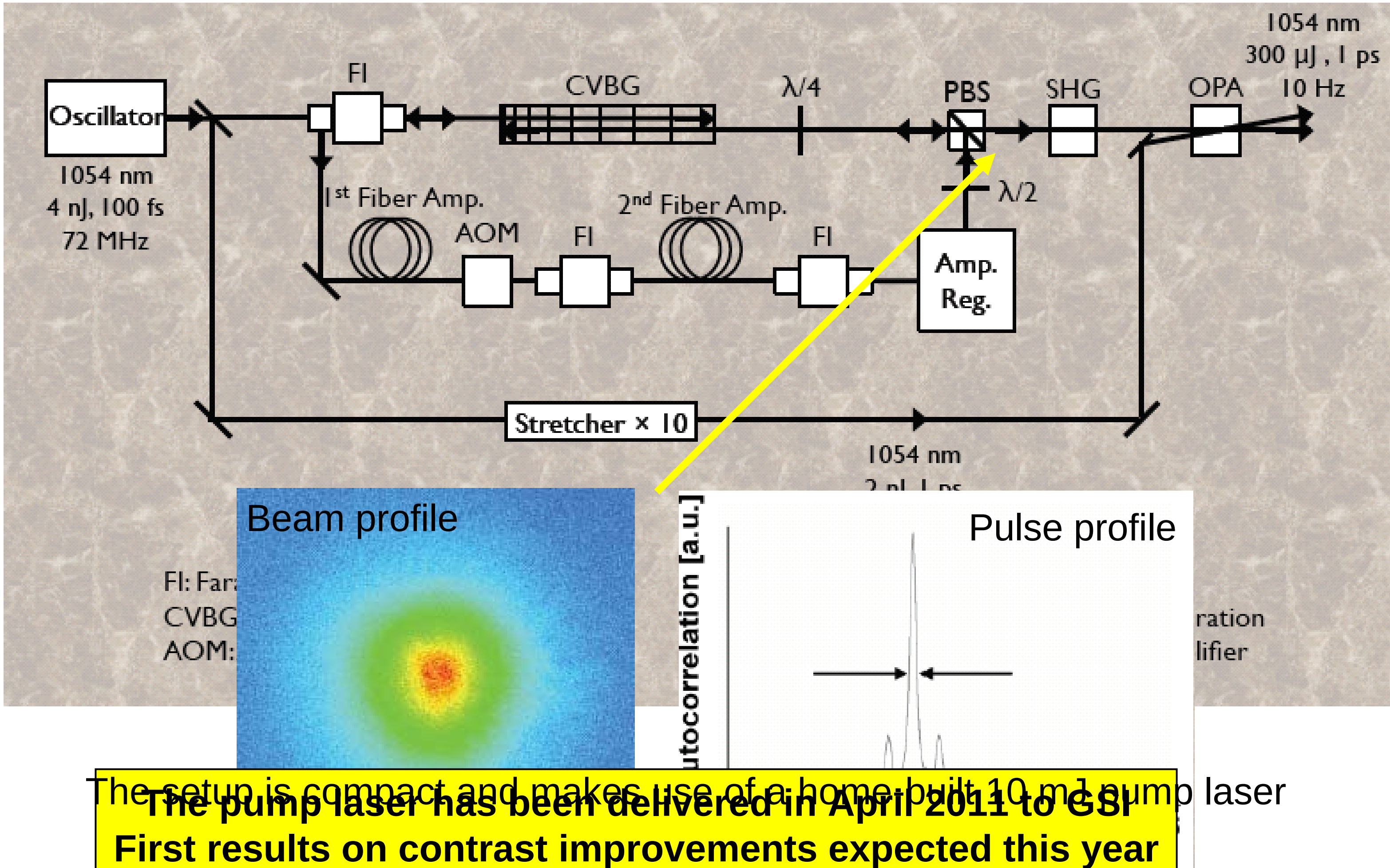
- **Light amplification leads to a temporal pedestal that limits the experimental capabilities of ultra-intensity lasers**



- **An ultrafast OPA works as a time-gated amplifier G = g(t), so that noise is not generated outside its picosecond amplifying time**

We are working on a scheme to improve the contrast of PHELIX by 5 orders of magnitude

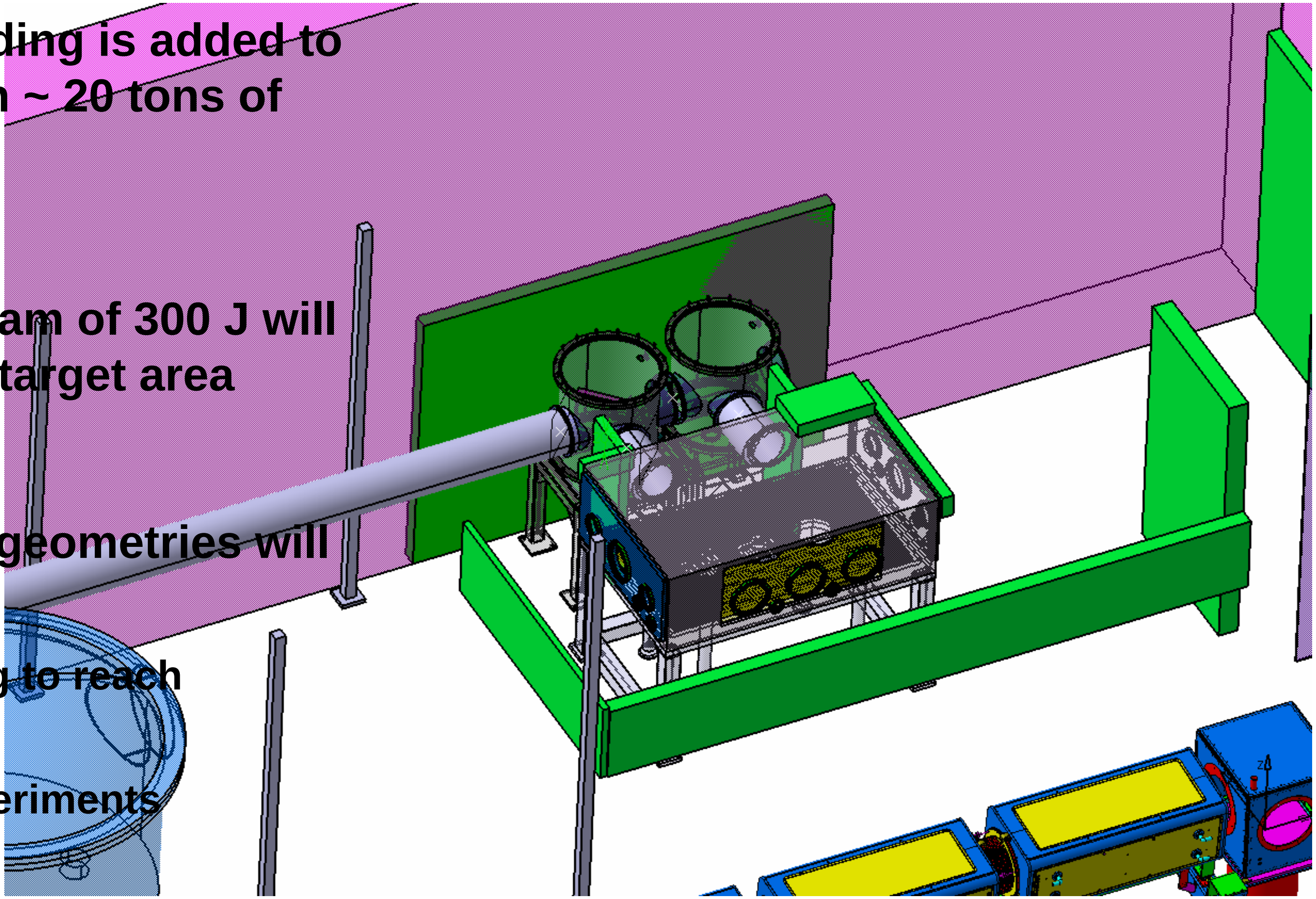
The Helmholtz Institute Jena has developed a pump laser suitable for an uOPA



The setup is compact and makes use of a home-built 10 mJ pump laser

The pump laser has been delivered in April 2011 to GSI
First results on contrast improvements expected this year

An upgrade to the petawatt area is being prepared



- An improved shielding is added to the target area with ~ 20 tons of steel
- The full PHELIX beam of 300 J will be available in the target area
- Different focusing geometries will be possible
  - Tight f/2 focusing to reach ~ 2 10^{21} W/cm^2.
  - Pump probe experiments

High shot rate lasers systems

- **In the context of emerging new projects (ELI), PHELIX may loose some of its attractiveness at the horizon 2020**
- **However there are many things that glass systems will be unique for:**
  - **Energy**
    - **One NIF beamline delivers 20 kJ of 1ω light!**
  - **Nanosecond and femtosecond options:**
    - **nanosecond lasers are very important for many interaction experiments**
  - **A glass system is a prefect pump laser for very short pulse lasers**

$$E_{pulse} \approx F_{saturation} \cdot S^*$$

    - **For a Ti:sapphire amplifier**
    - **For an Optical Parametric Amplifier**

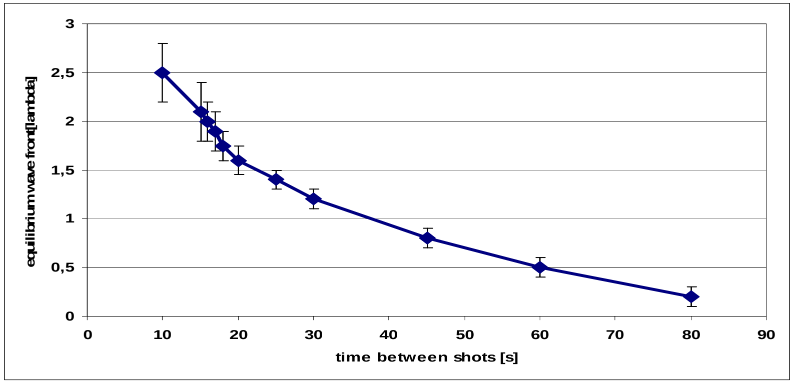
But thermal properties of glass have limited the operation of such lasers to single shot, so far

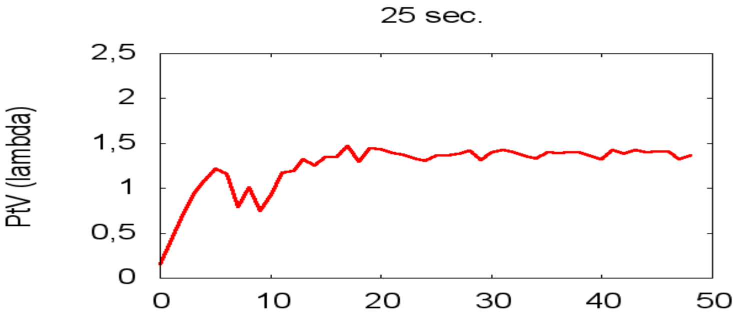
En route to higher shot rates

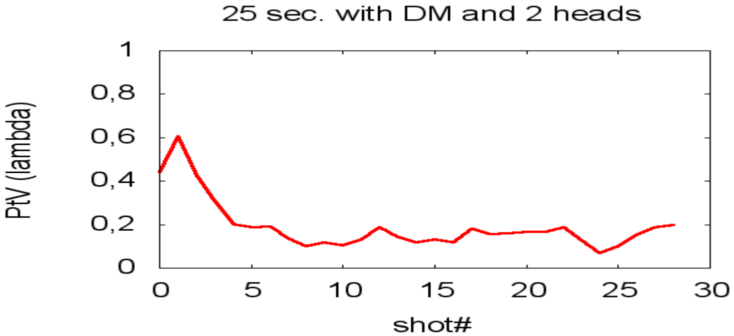
- **An amplifier shooting 1 per 10 minutes increases the output of PHELIX by a factor 10**
  - **There exists concepts how to reach this goal on a modified PHELIX design**
  - **Shielding must be increased**
  - **Targetry is still using the standard schemes but efforts must be done in detection**
- **An amplifier shooting 1 per minute increases the output of PHELIX by a factor of 100**
  - **The concepts for such amplifier may require a new amplifier**
  - **Shielding becomes problematic**
  - **Targetry must be significantly improved, huge efforts in diagnostic development must be made**

Towards higher shot rate at PHELIX (Pre-amplifier level)

- The normal waiting time between shot for thermal-aberration-free operation is 180 sec.
- When the repetition rate is increased, thermal aberration build up
- It is possible to work with active correction (deformable mirror) in the steady state







conclusion

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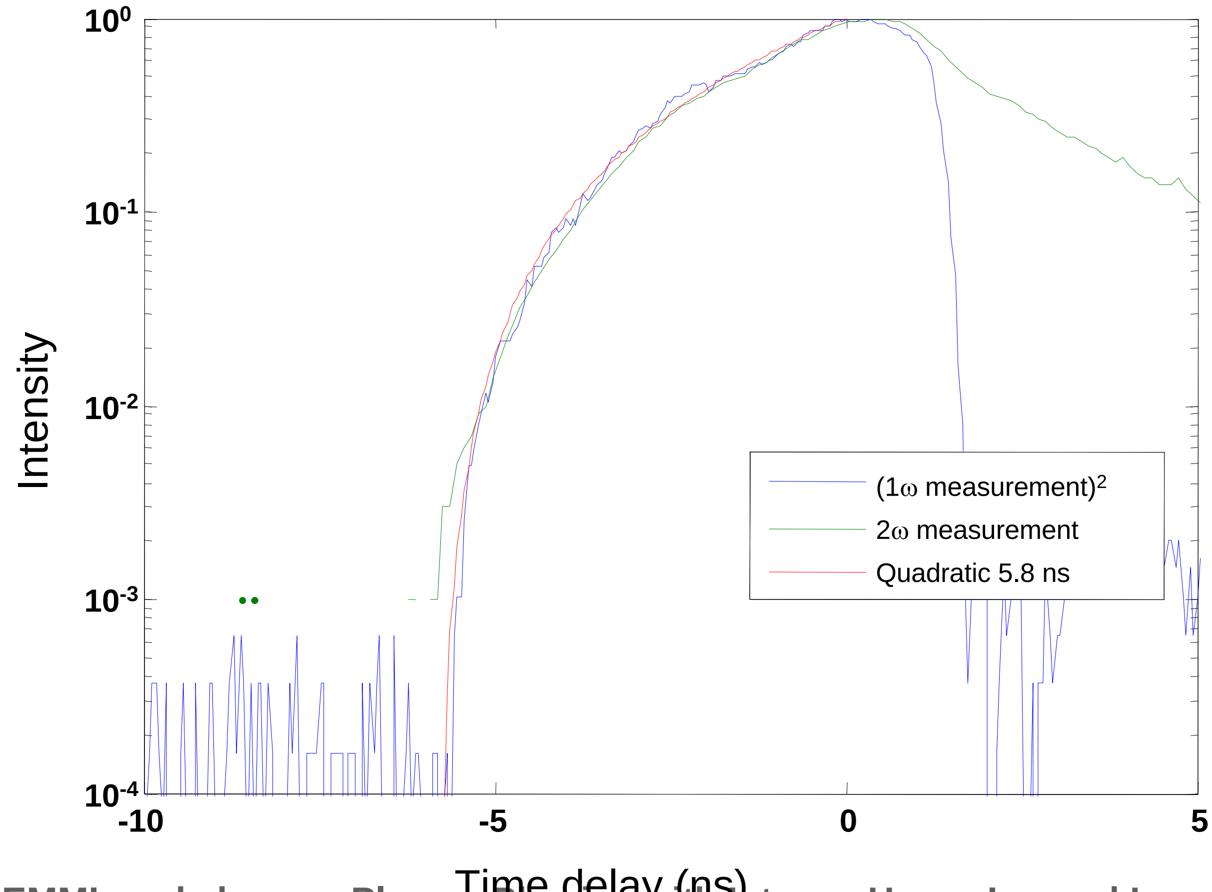
Thank You

Performance of PHELIX in 2011

	Long pulse 1ω	Long pulse 2ω	Short pulse
Pulse duration	0.7 – 20 ns	0.7 – 10 ns	0.5 – 20 ps
On-target energy	0.3 – 1 kJ	Up to 200 J	150 J
Maximum intensity	10^{16} Wcm^{-2}		10^{20} Wcm^{-2}
Repetition rate at joule level	1 shot every 3 min		
Repetition rate at maximum power	1 shot every 1h		
Temporal contrast	50 dB		60 to 80 dB depending on settings

Generation of parabolic pulses in the green

- **Comparison of our measurements at 1ω, 2ω and a 5.8 ns rise time parabolic profile**



Maximum energy: 561J, 1ω
172J, 2ω