Diagnostics of shock-compressed matter at X-ray facilities

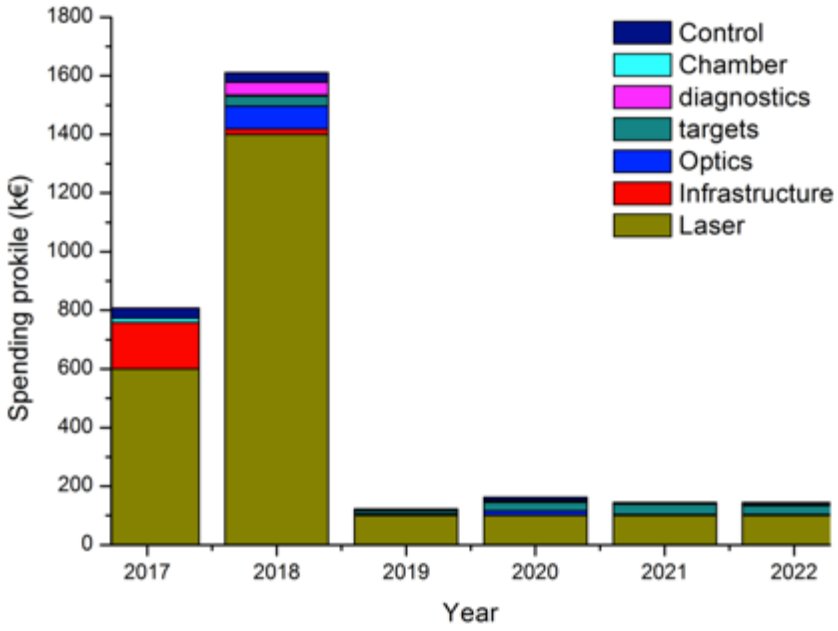
Dynamic Compression Workshop @ ESRF

30.03.2017

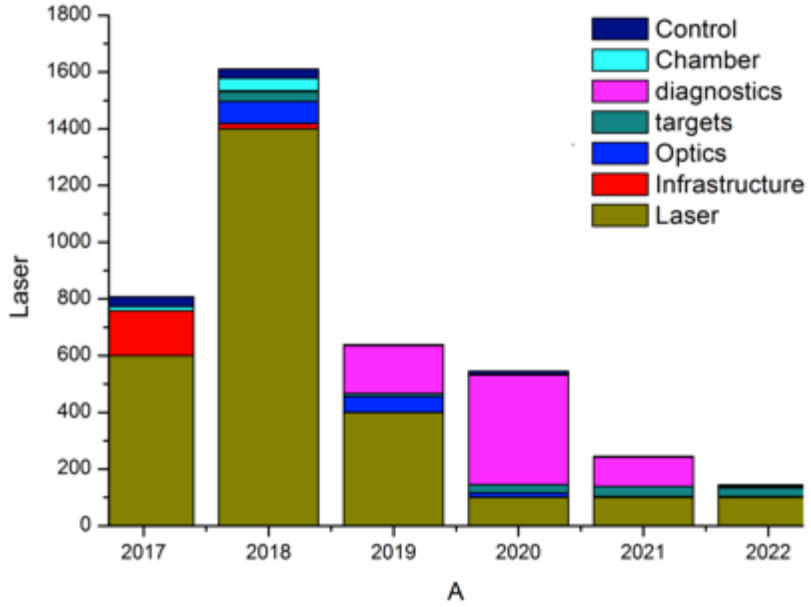
Dominik Kraus

Budget figure from HPLF-I CDR (June 2016)

ESRF funding

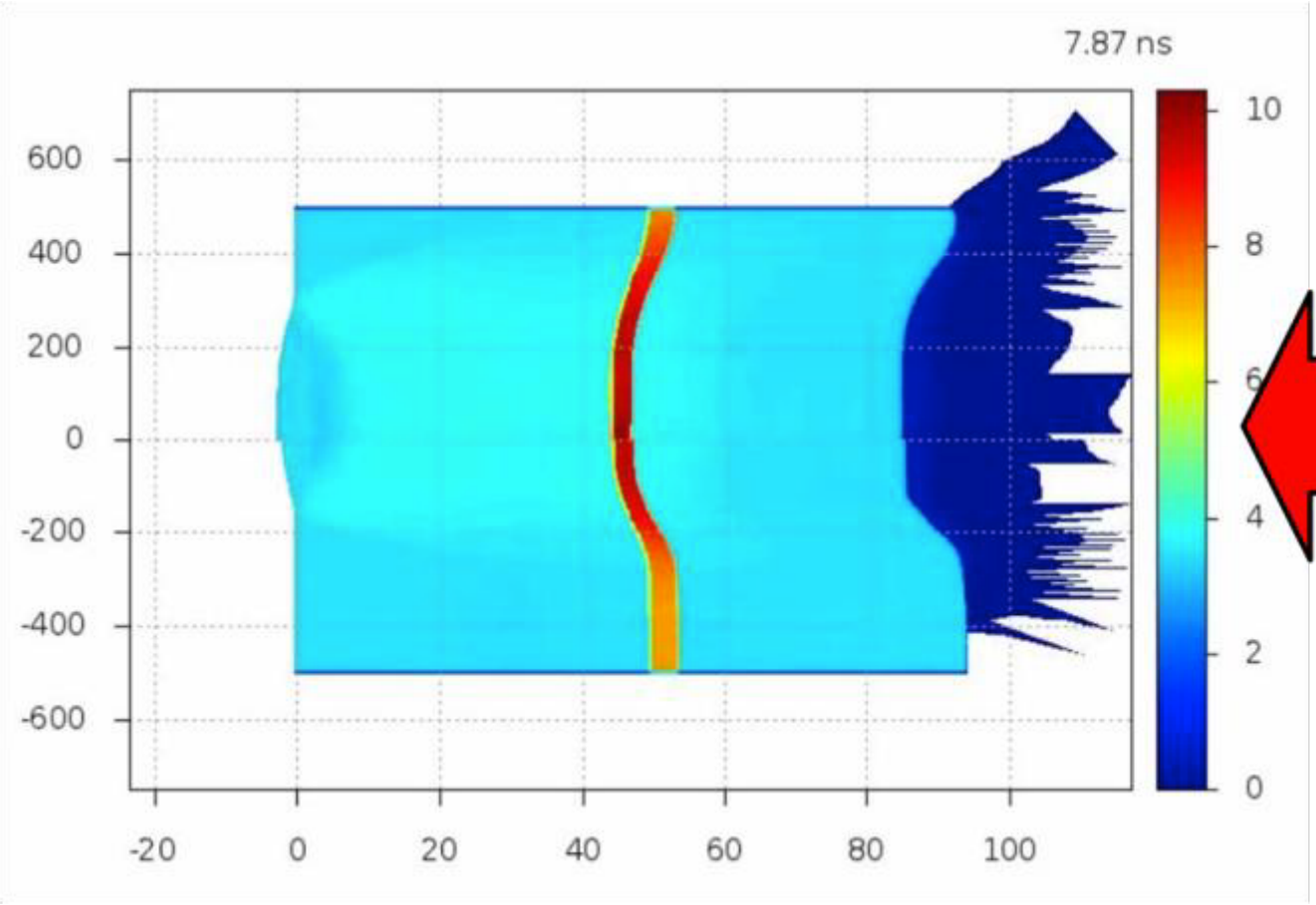


ESRF + external funding



First experiments planned for 2018 – limited diagnostics?

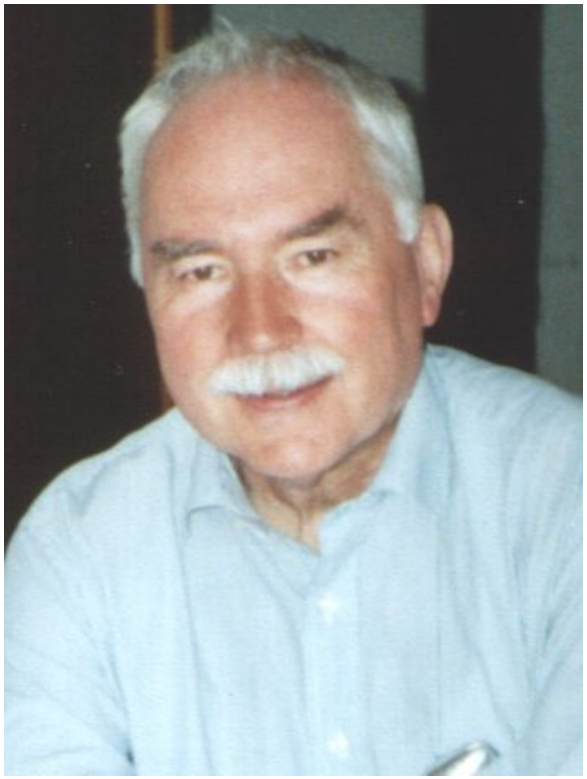
Shocks need diagnostics



X-rays 100 ps

LASER 10 ns

Shocks need diagnostics

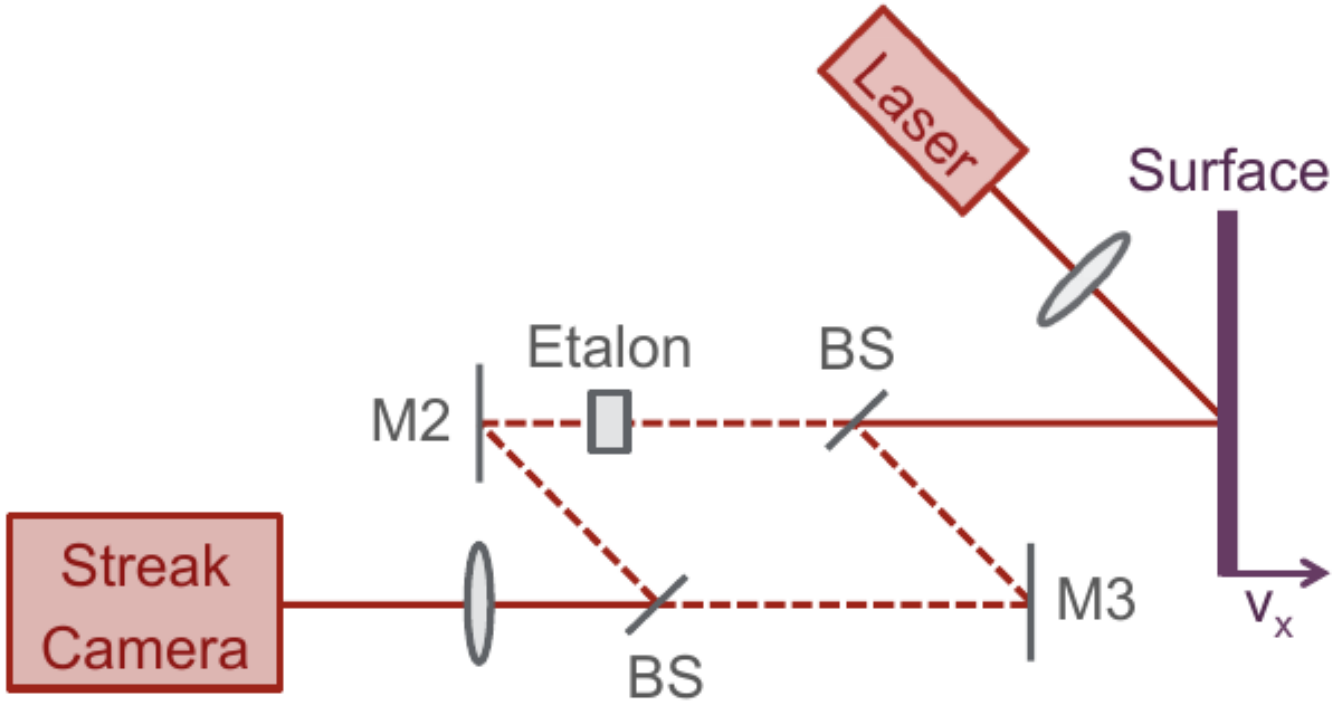


"All das Denken bringt es nicht, erst das Messen bringt's ans Licht."

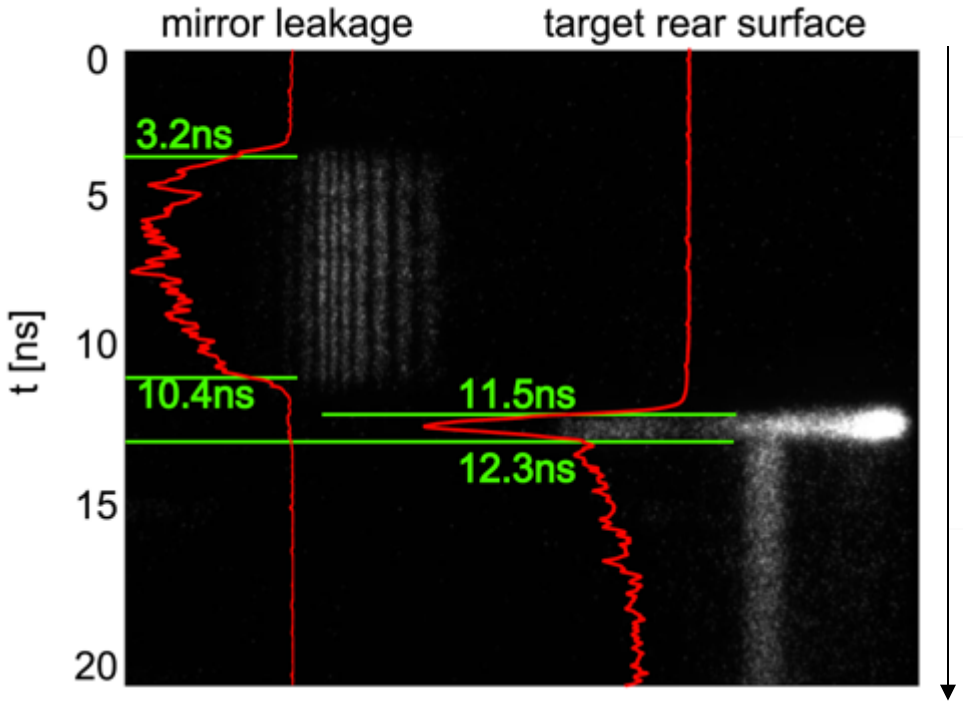
"Don't think too much, just measure it."

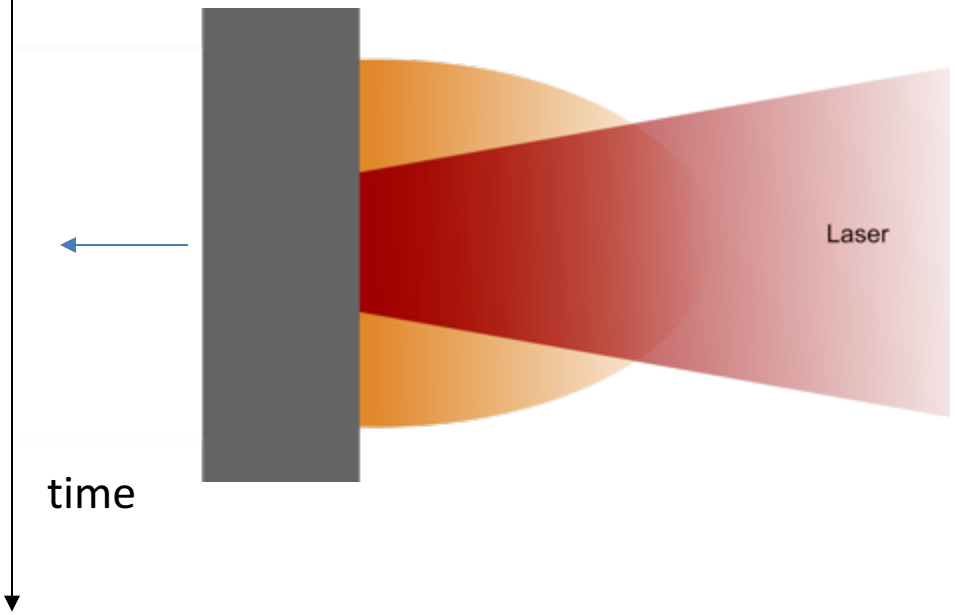
Achim Richter (TU Darmstadt)

VISAR diagnostics

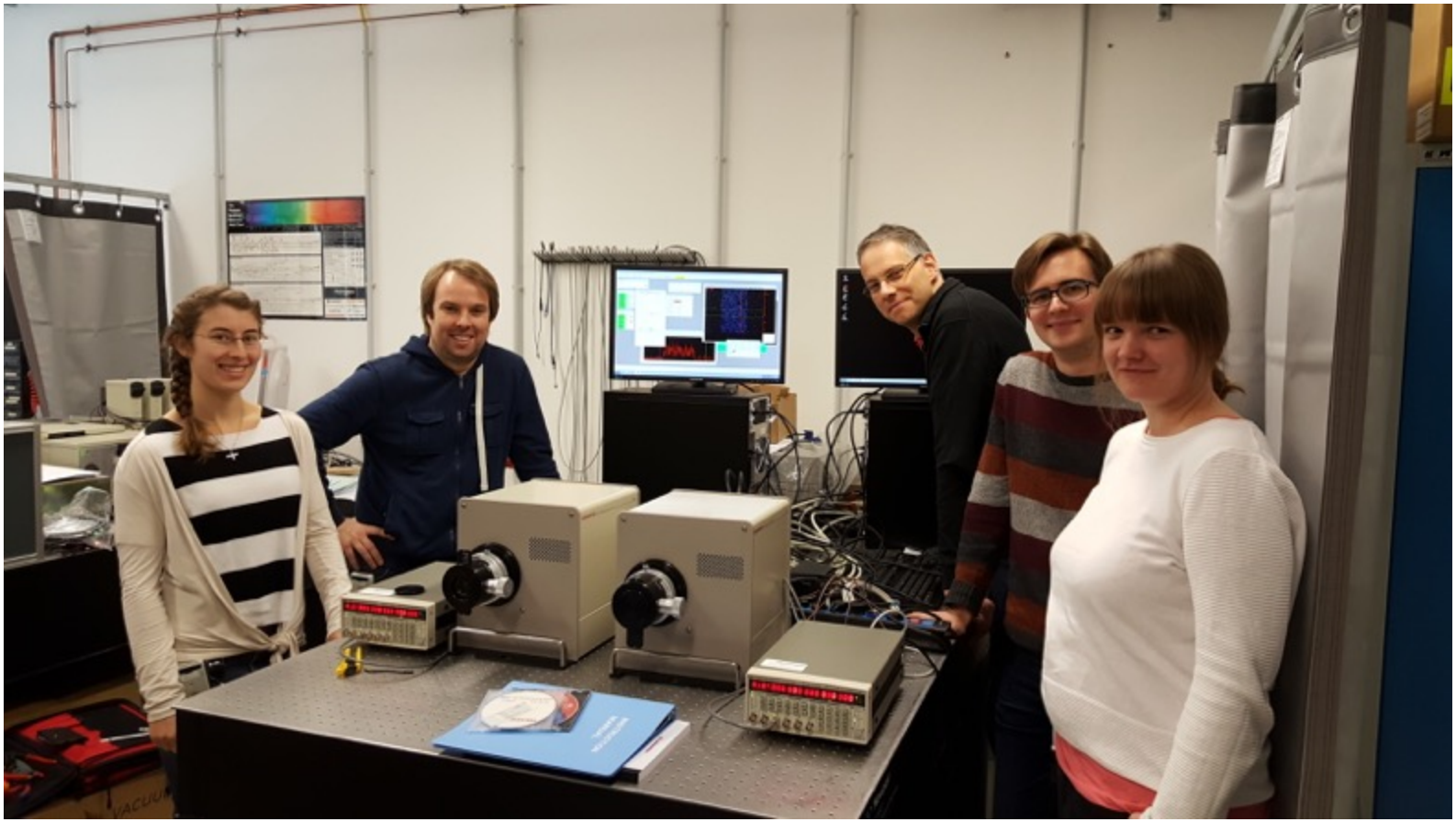


Streak cameras as diagnostics for laser experiments

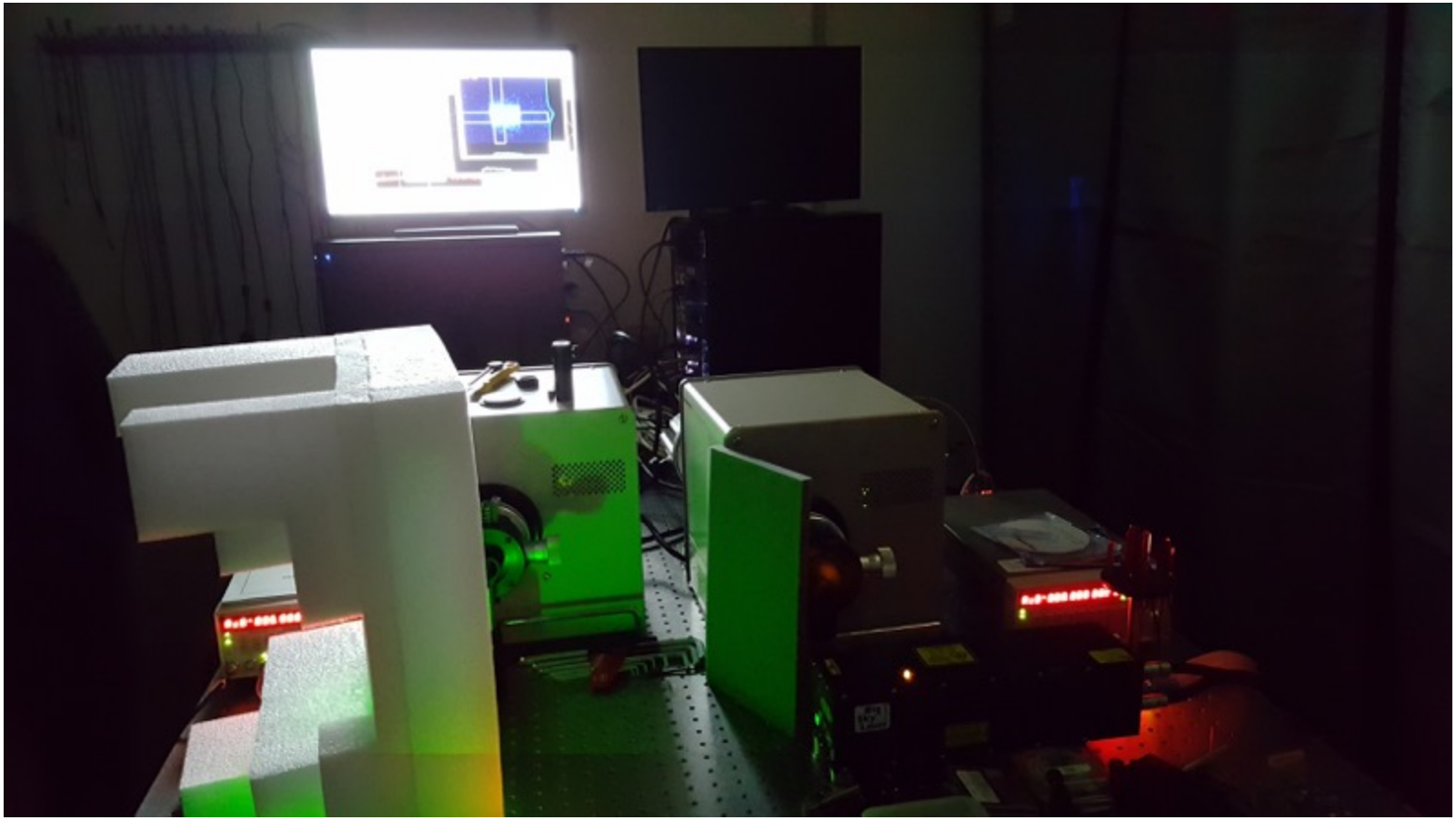




Two streak cameras at HZDR delivered recently (March 2017)



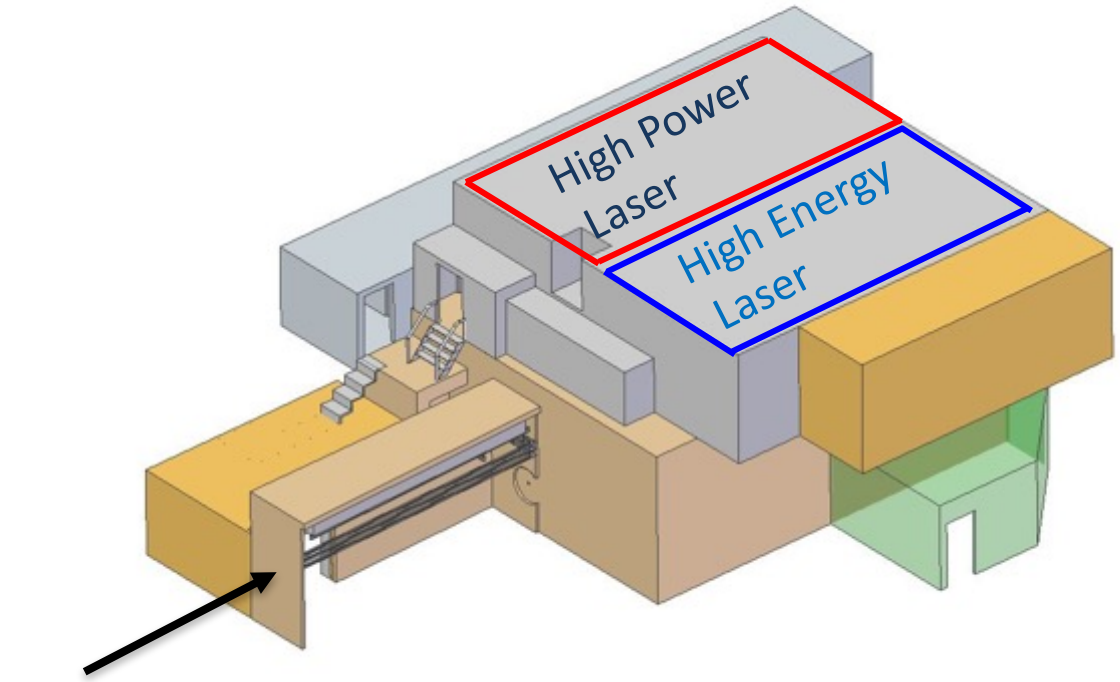
Two streak cameras at HZDR delivered recently (March 2017)



100 mJ/ 15 ns / 10 Hz pump laser
5 J / 10 ns / 10 Hz available

10 Hz targets needed

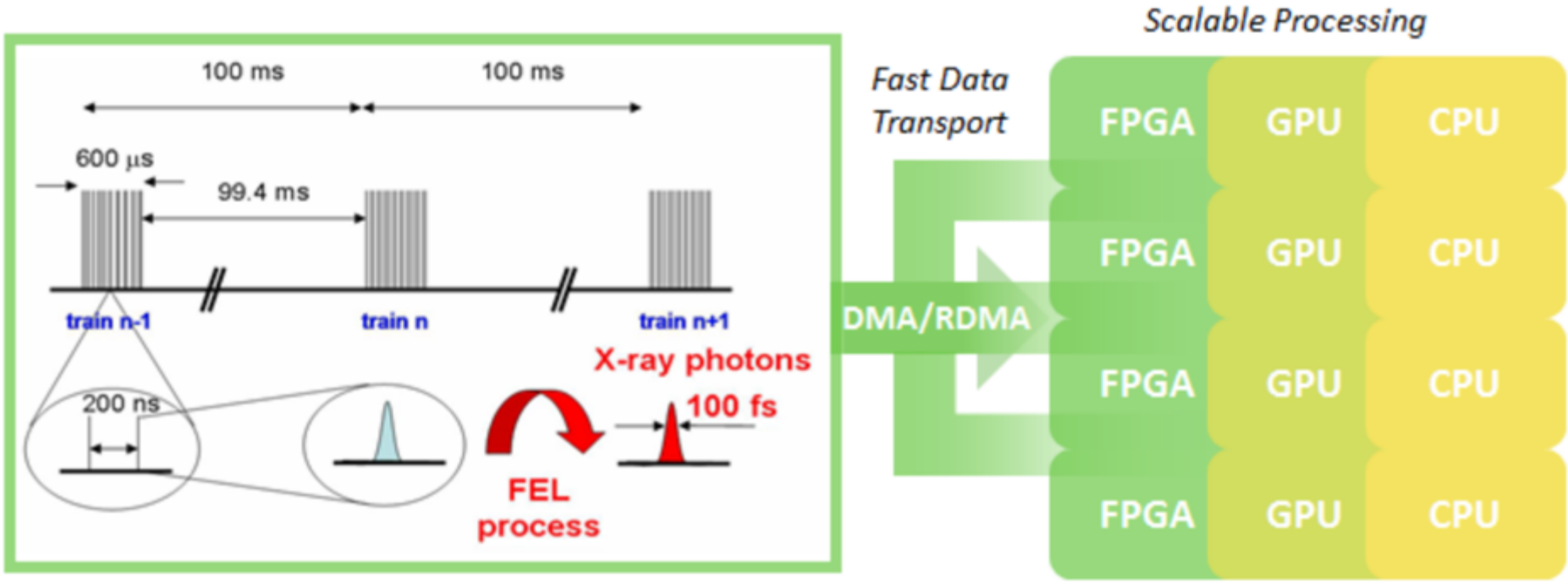
HED / HIBEF at European XFEL



Long pulse laser
few ns
100 J
10 Hz

Short pulse laser
200 TW
30 fs
10 Hz

EUCALL work package 5
Ultrafast data acquisition



Work package leader: M. Bussmann (HZDR)

High-speed VISAR analysis

High rate reconstruction of VISAR data for plasma physics experiments

F. Koller, C. Schulze

TU Dresden

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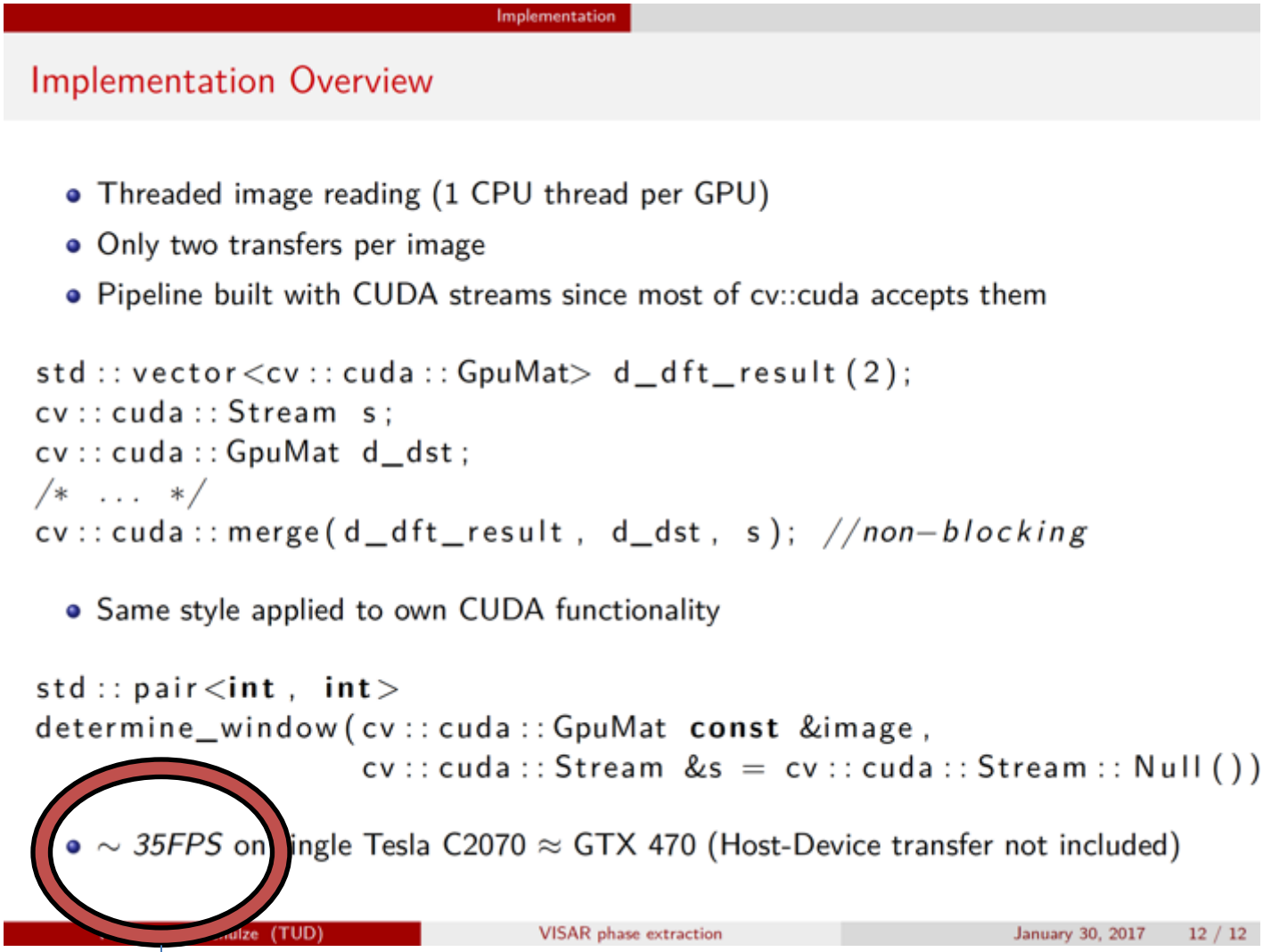
January 30, 2017

High-speed VISAR analysis



Implementation

Implementation Overview

- Threaded image reading (1 CPU thread per GPU)
- Only two transfers per image
- Pipeline built with CUDA streams since most of cv::cuda accepts them

```
std::vector<cv::cuda::GpuMat> d_dft_result(2);
cv::cuda::Stream s;
cv::cuda::GpuMat d_dst;
/* ... */
cv::cuda::merge(d_dft_result, d_dst, s); //non-blocking
```

- Same style applied to own CUDA functionality

```
std::pair<int, int>
determine_window(cv::cuda::GpuMat const &image,
                 cv::cuda::Stream &s = cv::cuda::Stream::Null())
```

- ∼ *35FPS* on ingle Tesla C2070 ≈ GTX 470 (Host-Device transfer not included)

ulze (TUD) VISAR phase extraction January 30, 2017 12 / 12

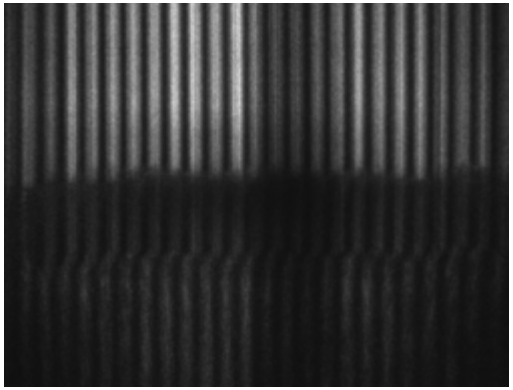
Reading data from HDD at the moment

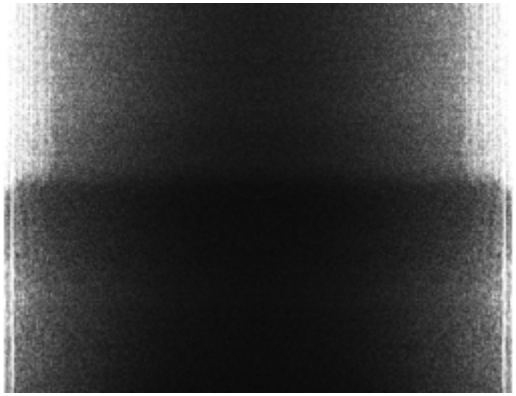
High-speed VISAR analysis

Original data

FFT

time

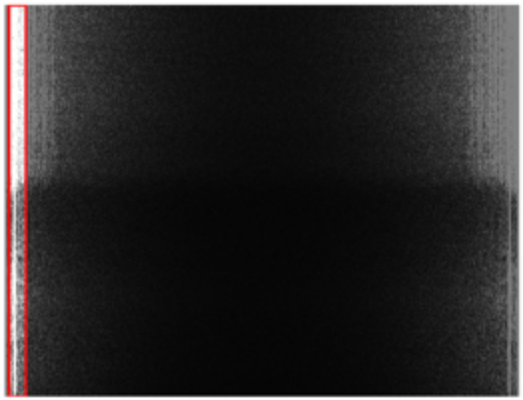


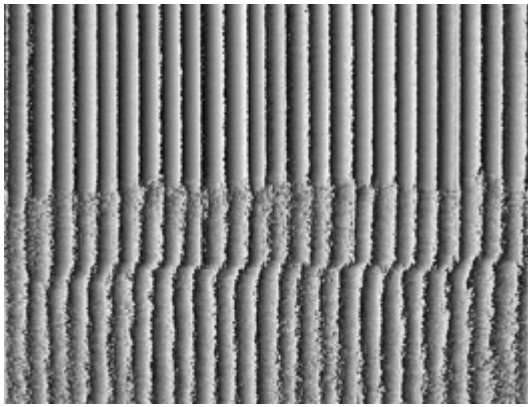


space

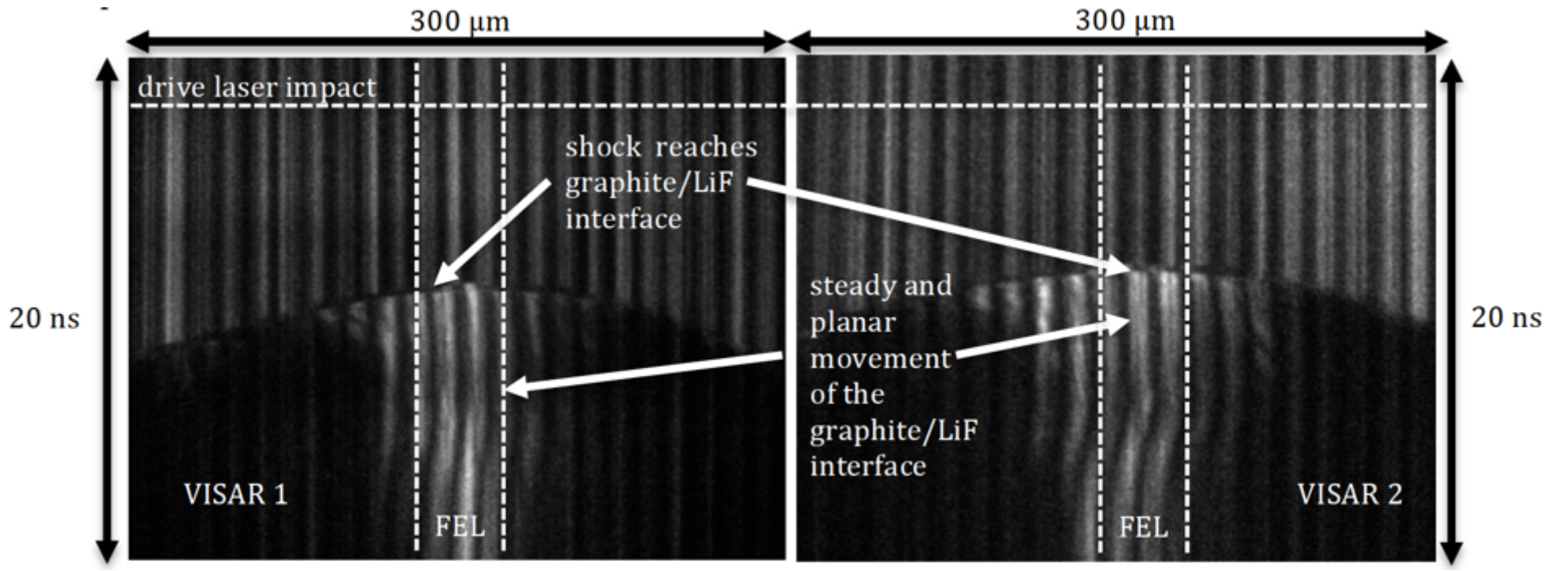
Filtering disturbing spatial frequencies

inverse FFT → Phase





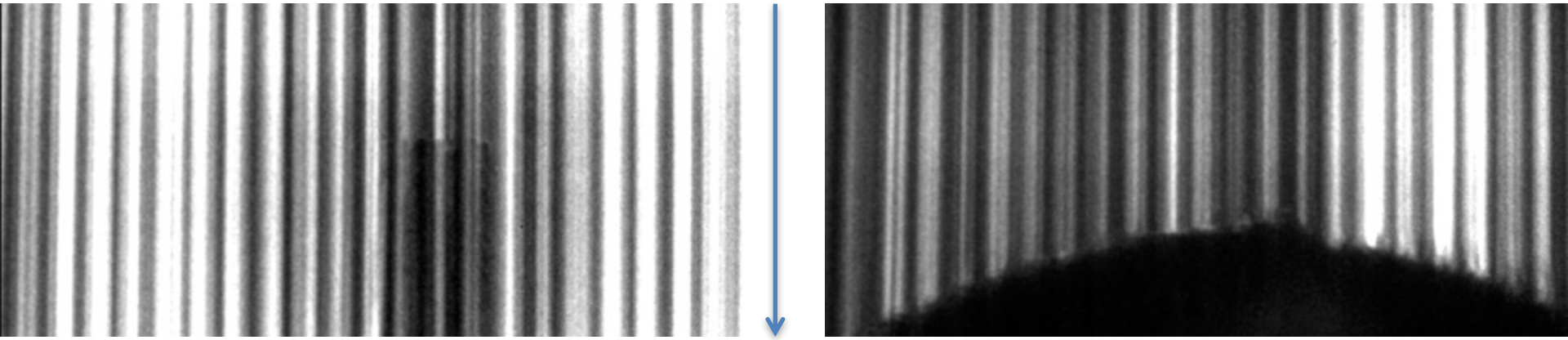
Pushing the limits: small sample volumes



Pushing the limits: small sample volumes

cold

driven

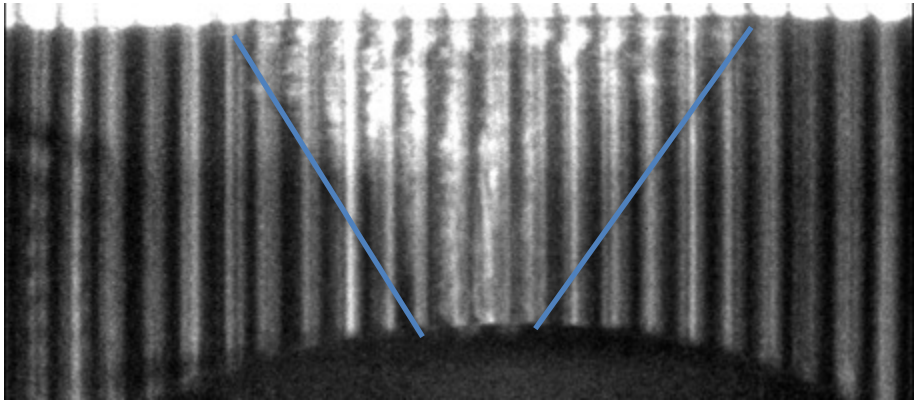


300 µm

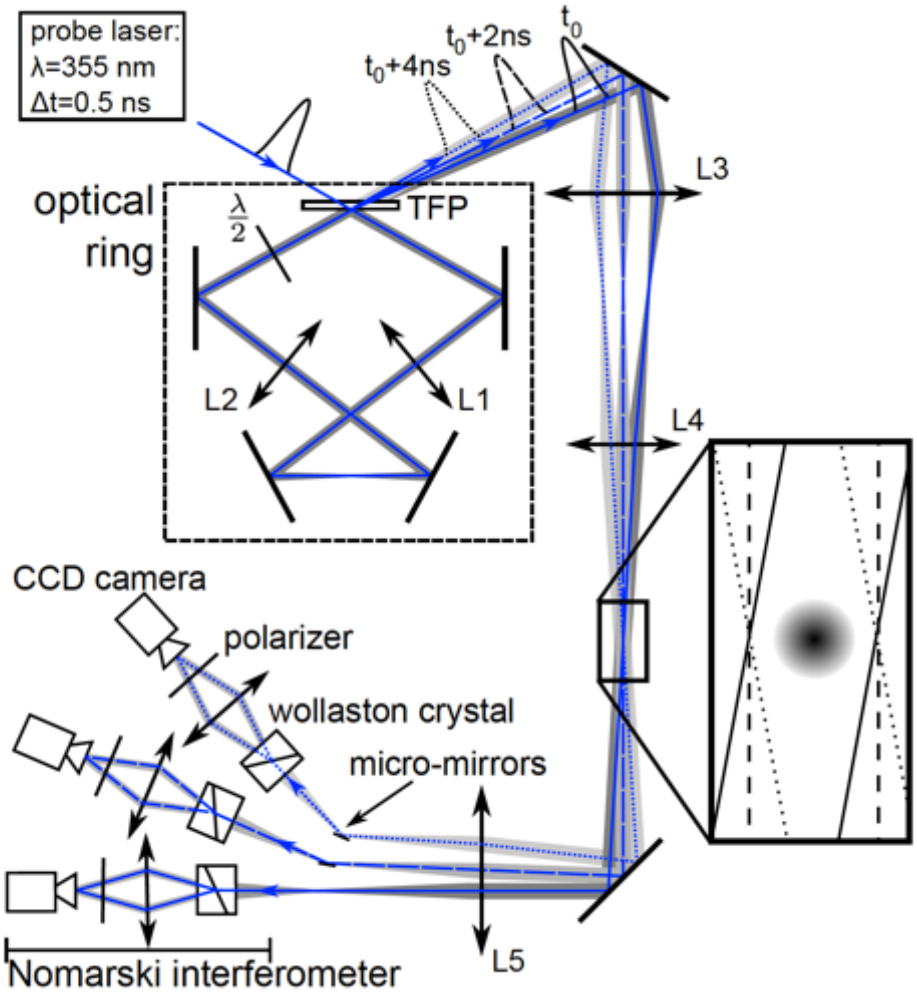
10 ns

300 µm

100 µm quartz sample:
shock front reflectivity
→ Rarefaction from the sides

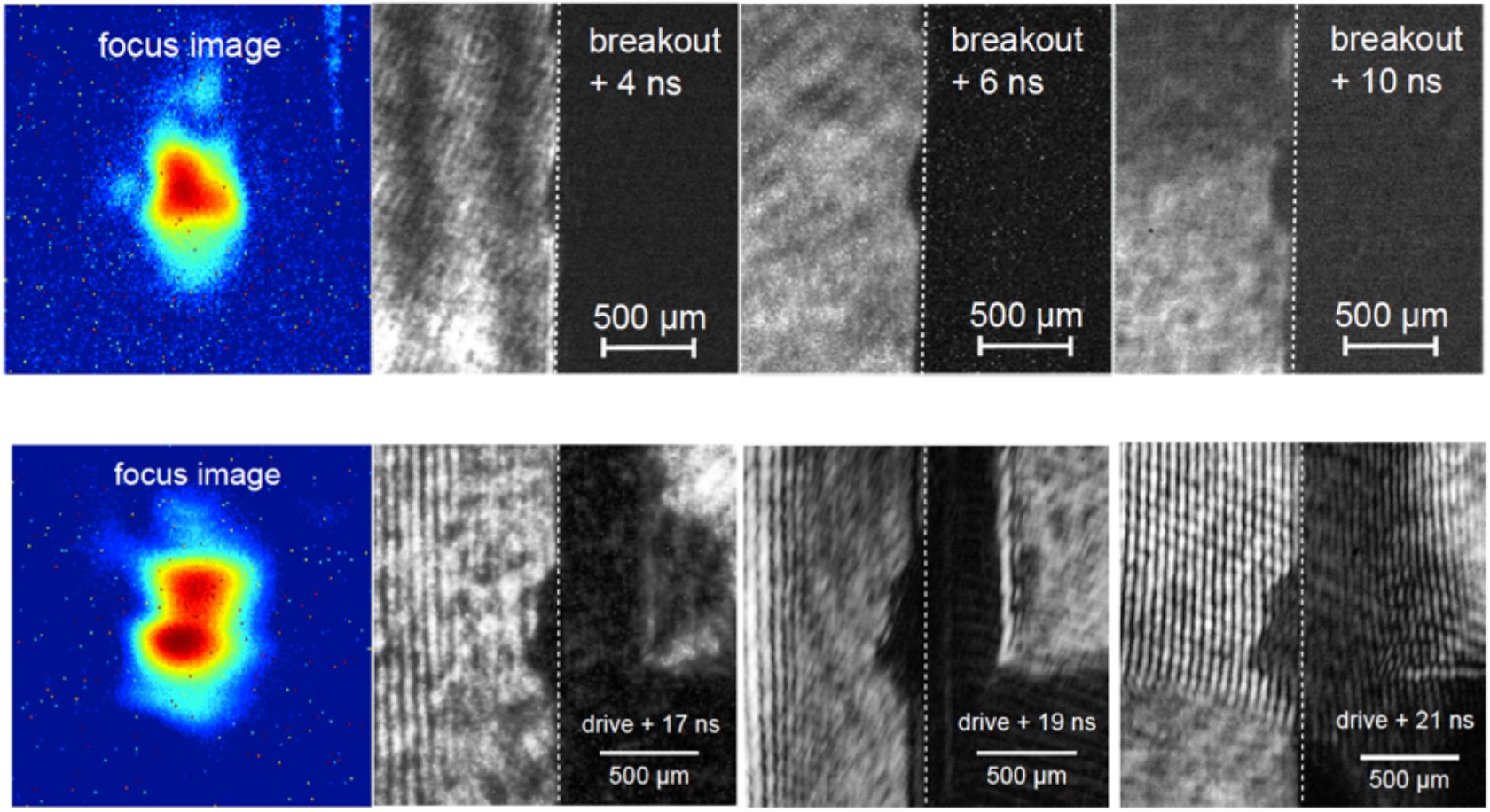


Optical Interferometry / Shadowgraphy

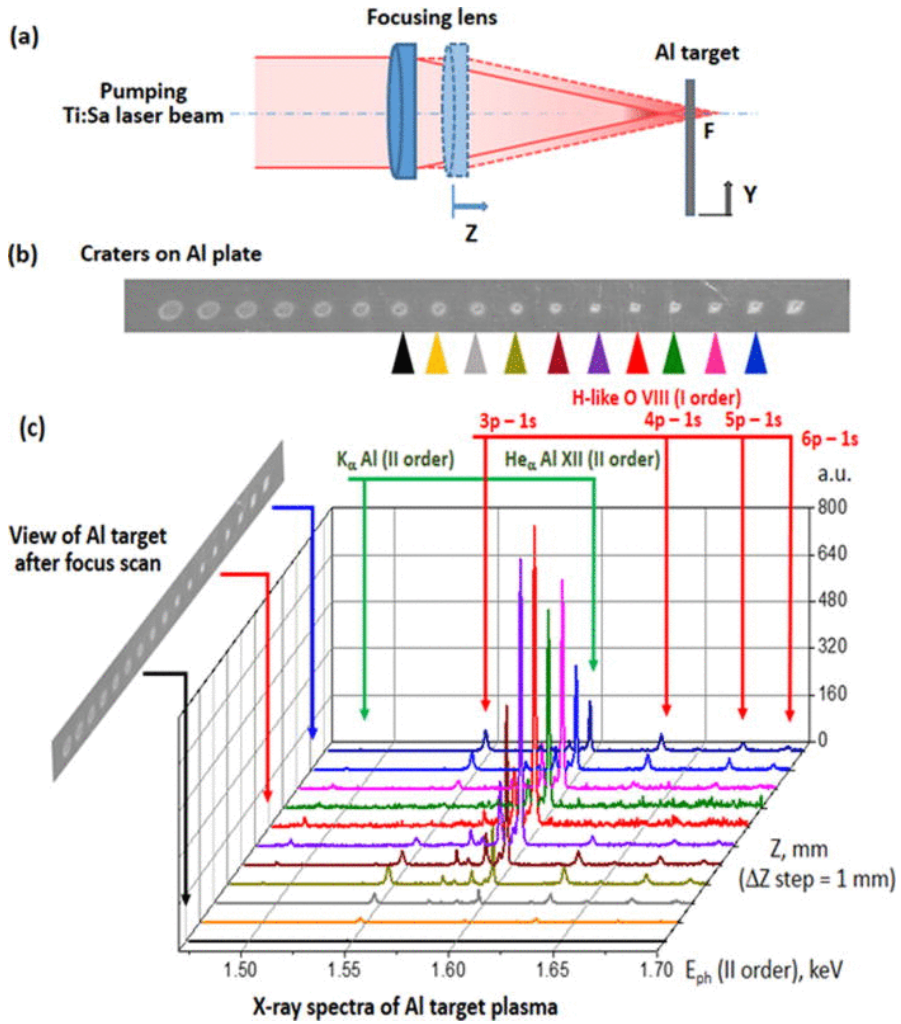


M. Börner et al.,
Rev. Sci. Instrum. 83 043501 (2012)

Optical Interferometry / Shadowgraphy



Emission spectroscopy: Assessing ablation pressure & preheat



T. A. Pikuz et al.
J. Appl. Phys. 120, 035901 (2016)

Using X-rays for shock timing

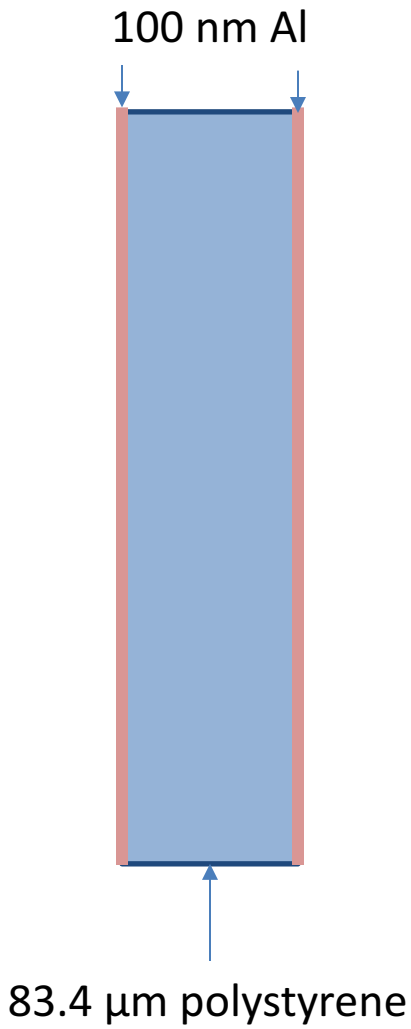
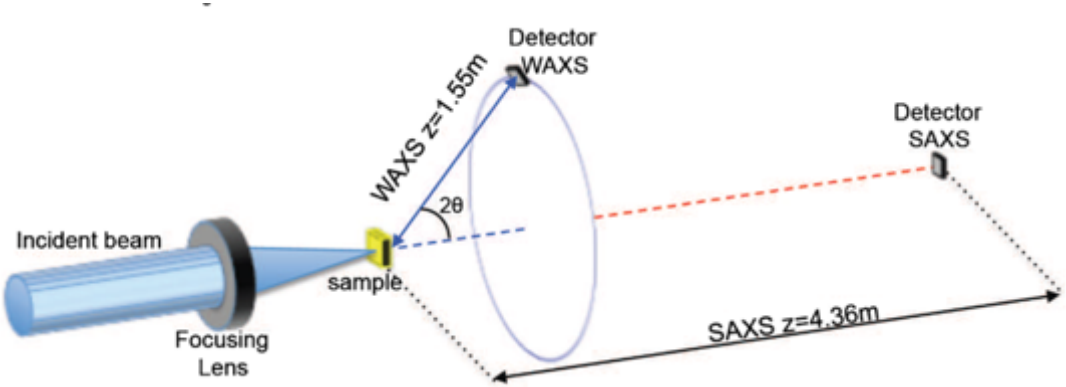


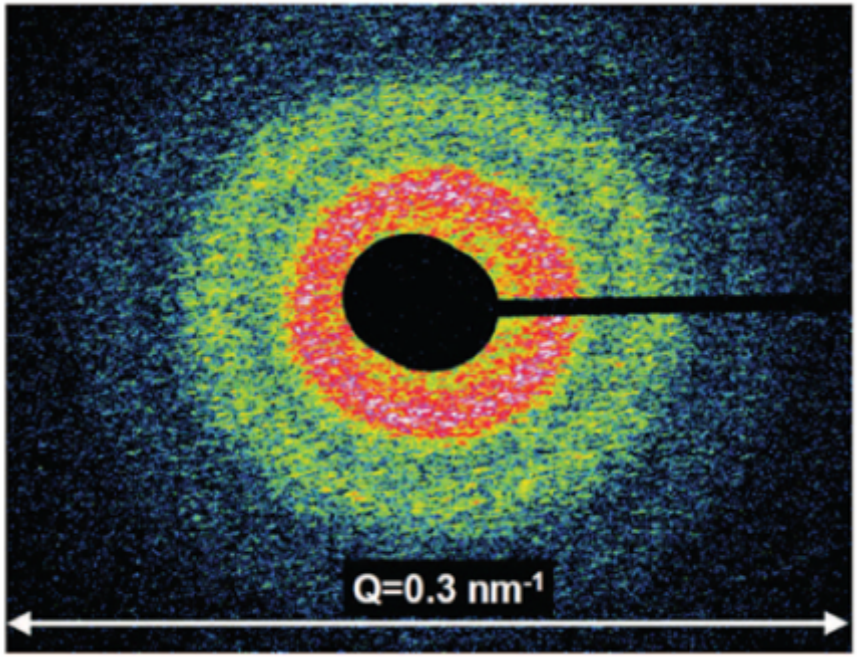
Figure removed: unpublished data

Imaging: material response and failure

Figures removed: unpublished data

Small angle X-ray scattering: Grain sizes, interfaces





Sensitive to few nm features:

- structures too small for imaging
- too large for diffraction

C. Gutt et al., Phys. Rev. Lett 108 024801 (2012)

Temperature

SOP

Debye-Waller-Factor

EXAFS

….

Should try to realize all together

Warm dense matter research at HZDR

Experiment

Dominik Kraus
Helmholtz Young Investigator
Group Leader

Nicholas Hartley
Postdoc
Joint appointment with
Osaka University

Anja Schuster
PhD student

Katja Rohatsch
PhD student

Theory

Jan Vorberger
Scientist in HZDR's
"high potential" program

Kushal Ramakrishna
PhD student

Also at HZDR: HiBEF

PIConGPU

DRESDEN concept

HZDR

Conclusions

- Having various shock diagnostics are important and should be available for HPLF from the beginning

- Need to be provided from Users

- Many synergies with other European or international labs towards high-energy laser experiments at higher repetition rate

“ There is nothing about this story that isn’t totally cool. Lasers! X-rays! Asteroid impacts! Precious gems! … “

Thanks