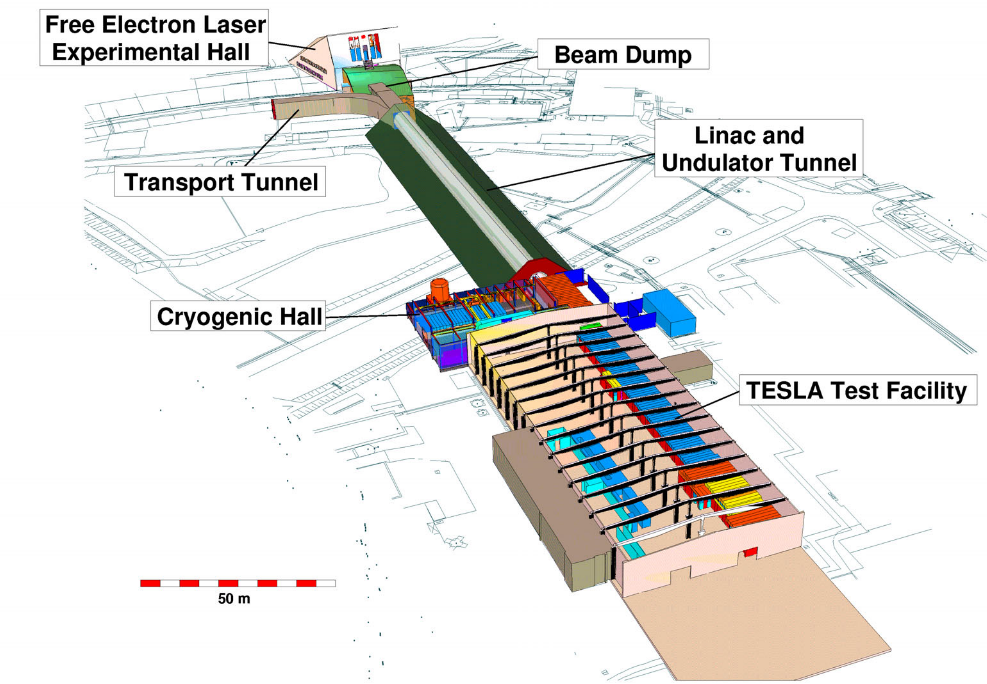
The SASE FEL at DESY: Photon beam Diagnostics for the User Facility

K. Tiedtke for VUV FEL collaboration



SRI 2003, San Francisco, Aug. 25, 2003 Kai.Tiedtke@desy.de

Outline

- Introduction
- Layout of the experimental hall
  - basic requirements
  - optical system
  - attenuator
- Photon diagnostics
  - intensity-monitor
  - VLS spectrometer
- Conclusion

Introduction

SASE FEL at the TESLA TEST Facility at DESY

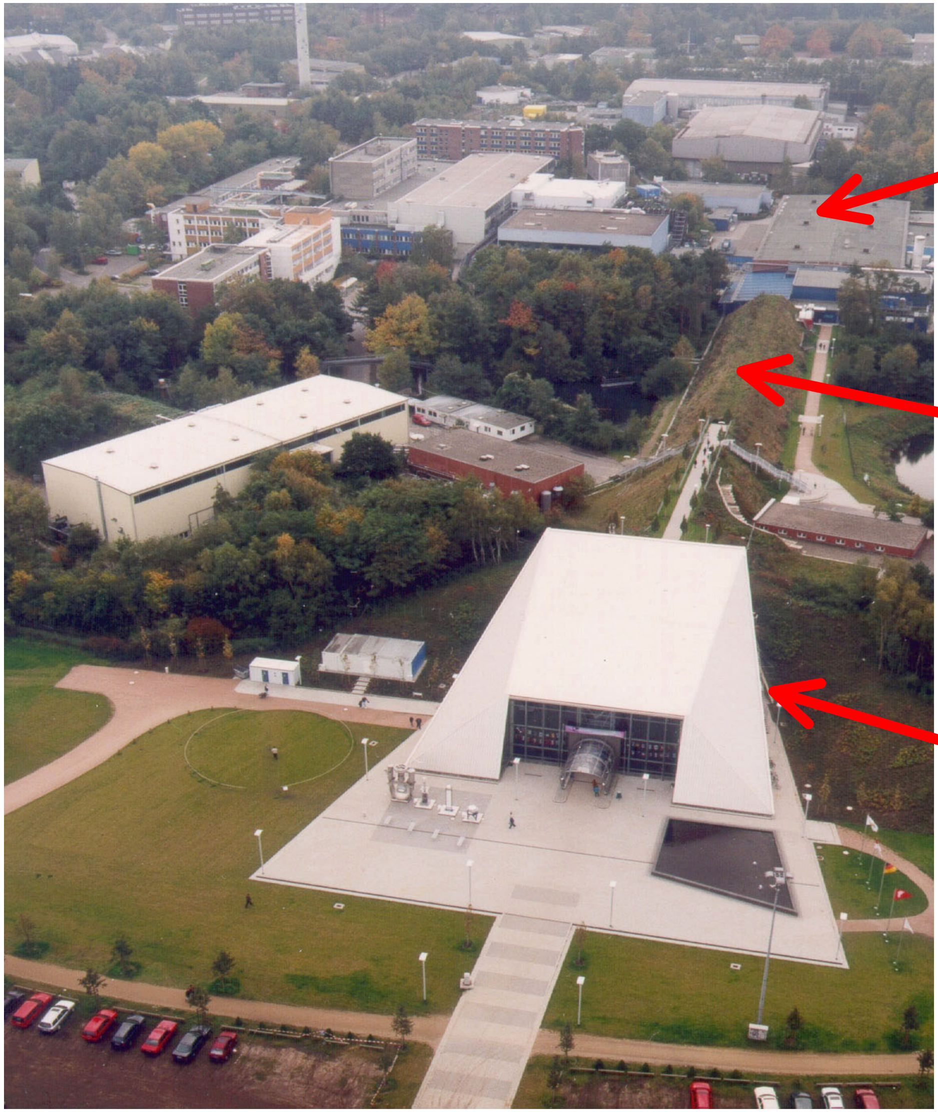
- 2000 First self amplified spontaneous emission (SASE) around 108 nm
- 2001 SASE FEL gain up to saturation was reached between 80 – 120 nm
- End 2001 – 2002 First set of user experiments on the interaction with cluster beams and surfaces
- Currently the linear accelerator is being upgraded to 1 GeV which will provide radiation wavelengths down to 6 nm

SASE FEL properties

- high intensity (GW peak power)
- coherence
- femtosecond pulses
- narrow bandwidth
- wavelength tunability!

VUV FEL user facility

VUV FEL at the DESY



Phase1

- 80-120 nm
- 30-100 µJ
- 1 GW_{peak}
- 30-100 fs

Linac and FEL extension for Phase2

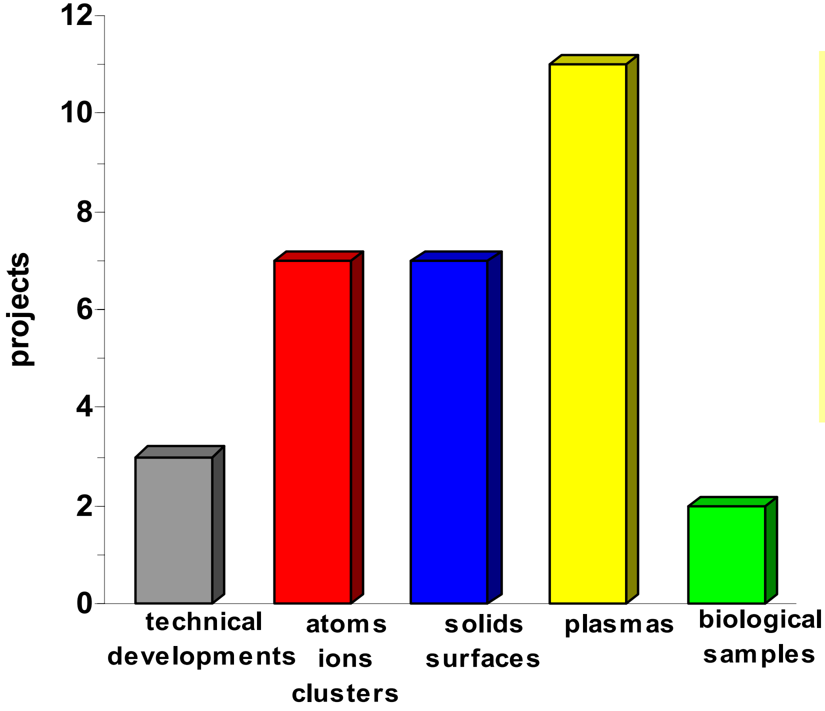
Experimental hall (User Facility, starting 2004)

- 6 - ~120 nm
- 0.1 – 1 mJ
- 30 - 400 fs

VUV FEL parameters

Electron beam	
Energy	0.2 – 1 GeV
Number of bunches per train	up to 7200
Repetition rate	1 - 10 Hz
Bunch charge	1 nC
FEL radiation	
Wavelength	120 – 6 nm
Pulse energy	0.1 – 1mJ
Pulse duration (FWHM)	30 – 400 fs
Peak power	0.3 - 2.8 GW
Spectral width (FWHM)	~0.5 %
Spot size at the undulator exit (FWHM)	1.4 – 0.14 mm
Angular divergence (FWHM)	170 – 24 mrad
Peak brillance	$1\text{x } 10^{28} – 3\text{x}10^{30}$ (photons/sec/mrad^2/mm^2/0.1%bw)

Areas of Proposed Research



- 30 proposals submitted
- very high scientific quality
- total beamtime requested:
  98 weeks for the first year
  (49 weeks if two shifts per day)

What are the basic requirements for doing an experiment on the FEL?

- A nice focal spot of some μm on the sample
- Control of wavelength, pulse timing, intensity etc.
- Online information on all relevant beam parameters
  SASE specific shot-to-shot fluctuations↓ for every single pulse!

- **FEL beam transport**
  - stable beam direction, keep on reference orbit
  - stable, reproducible optical systems for deflection, focusing, beam splitting without degrading coherence and pulse duration

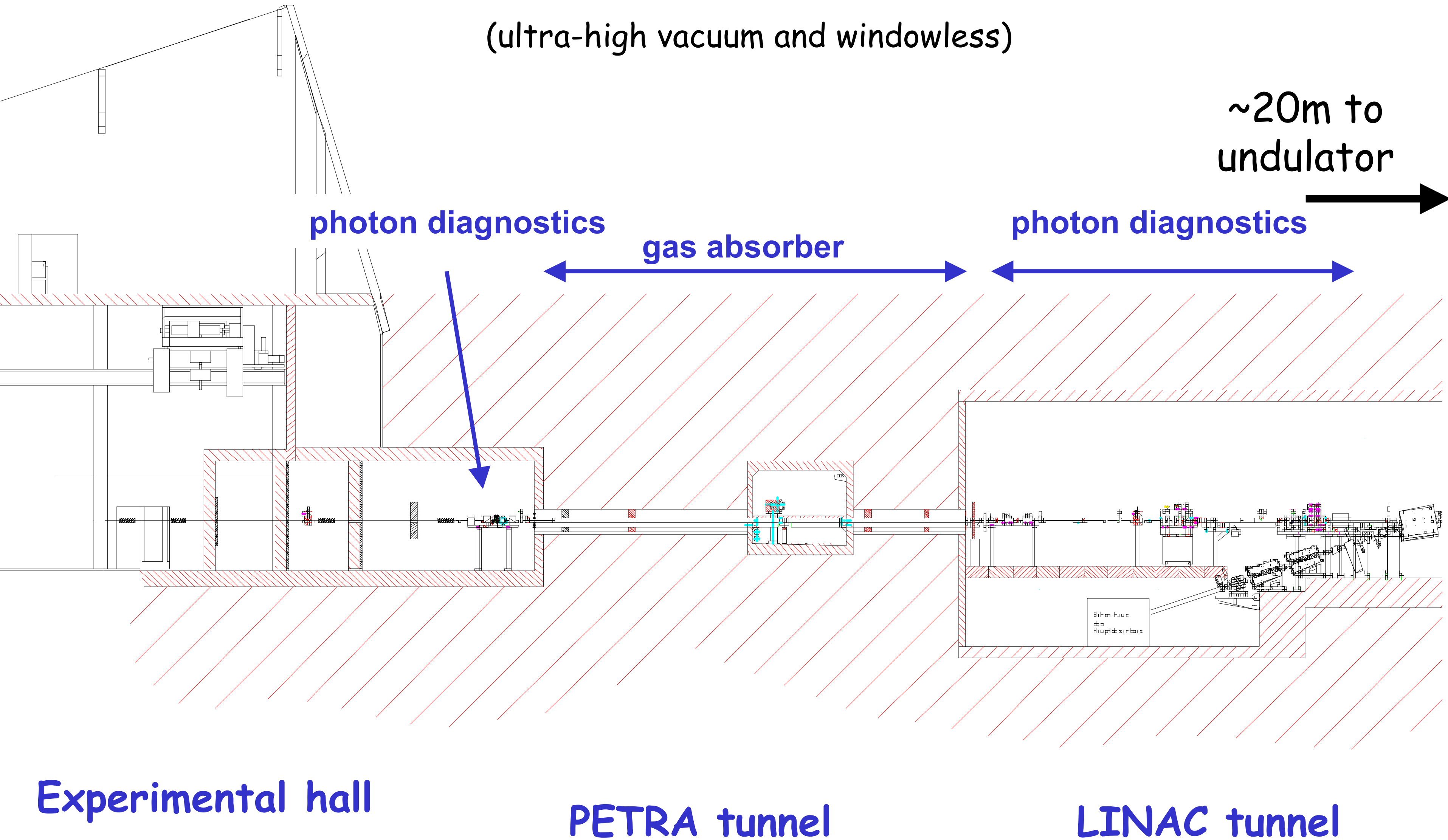
a few μrad

- **FEL beam diagnostics: Online, single pulse**
  - Pulse energy
  - Intensity distribution
  - Spectral distribution, coherence
  - Temporal structure and exact timing ↓

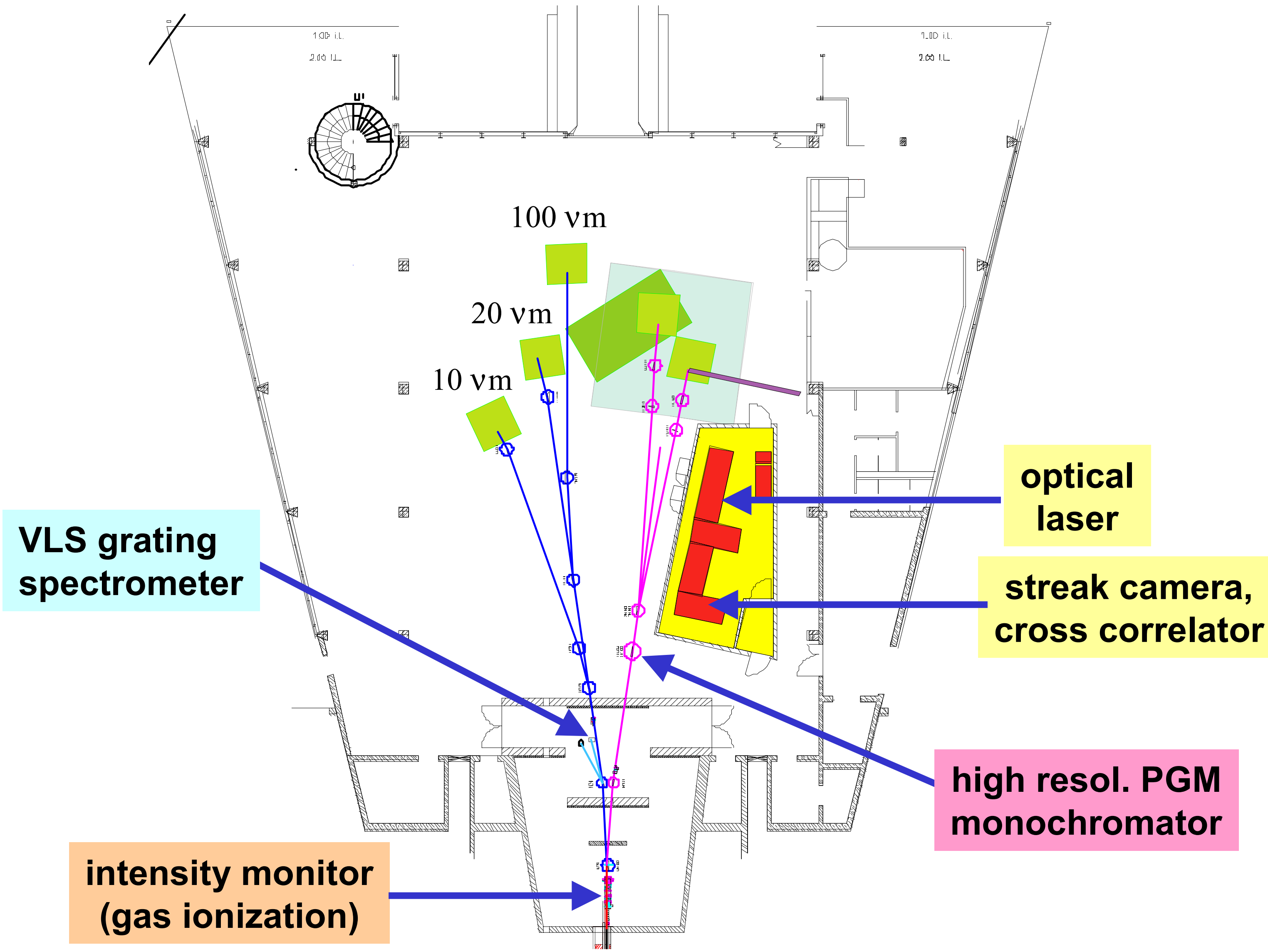
No results, but ideas

Photon beam transport

(ultra-high vacuum and windowless)

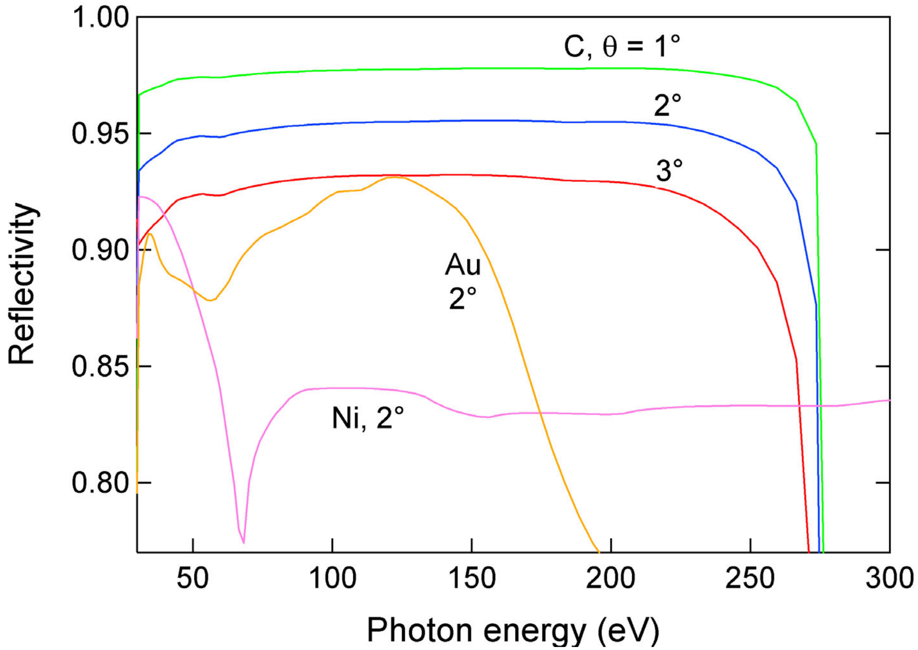


Layout of experimental hall



Mirrors for FEL radiation

Reflectivity



Plane mirror -> beam distribution

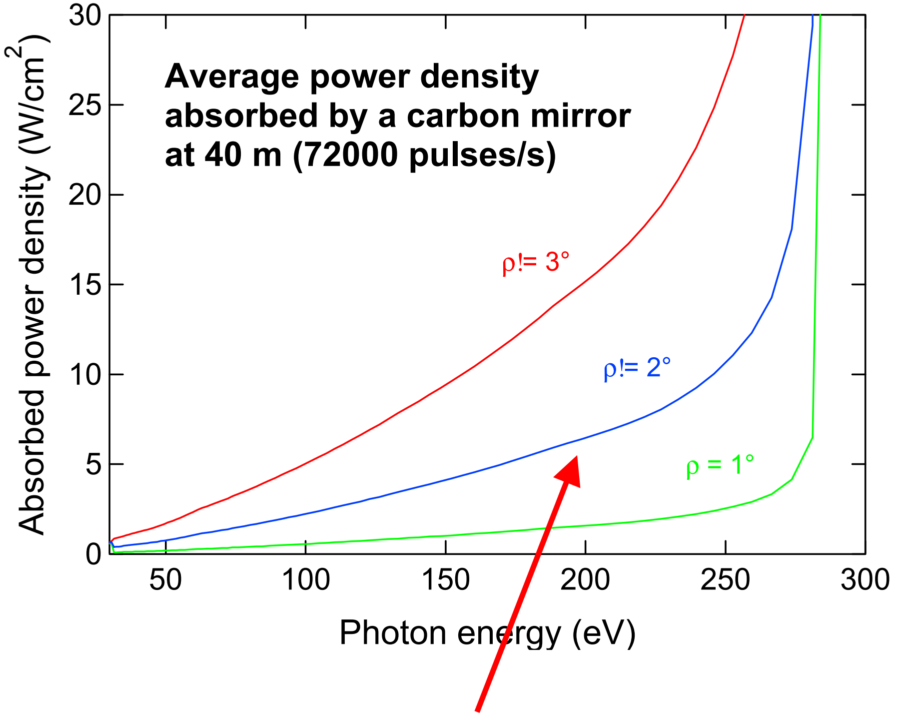
Toroidal & ellipsoidal mirror -> focusing

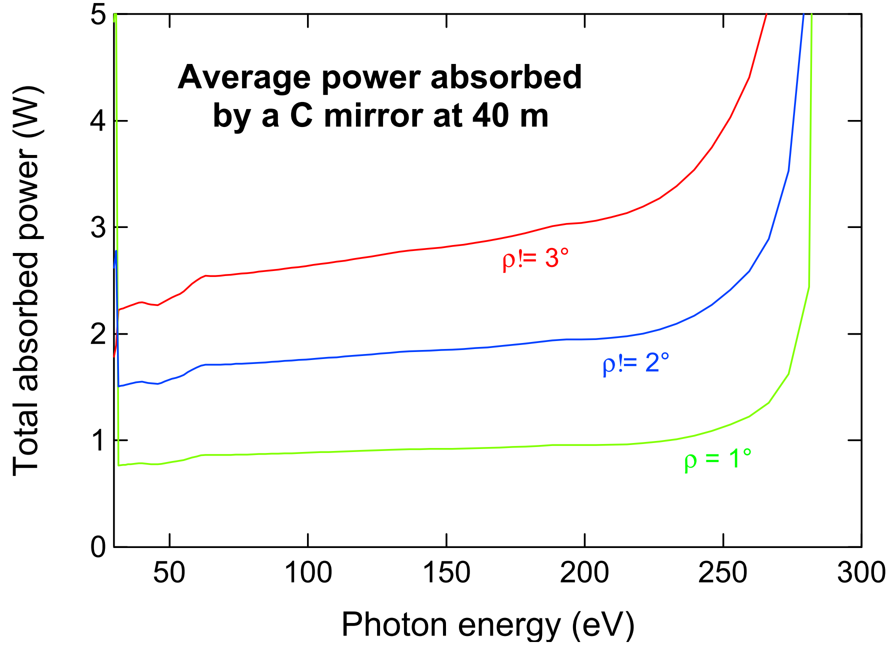
Substrate: Si

Mirror dim.: 50 cm x 6 cm

Coating: C for the fundamental

Power load on FEL optics

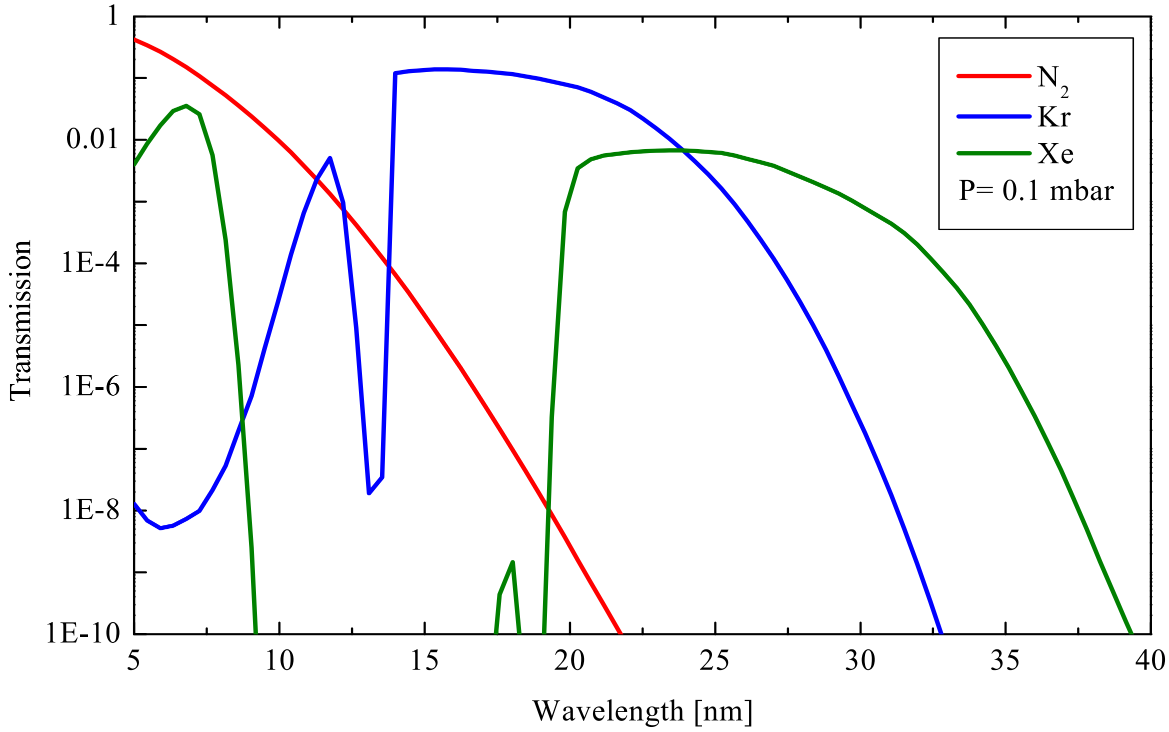




2 orders of magnitude below the ablation threshold of approx. 100 mJ/cm^2

Controlled attenuation of the FEL radiation

Calc. transmission of a 15m long gas absorber



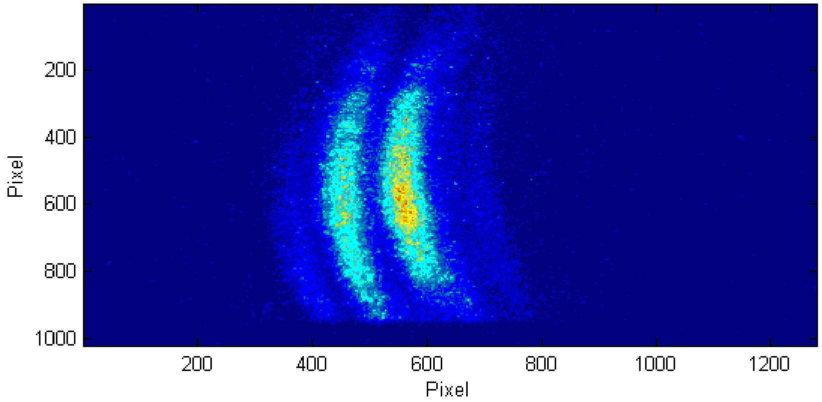
Gas absorber cell
(length: 15 m, Ø: 35 mm)

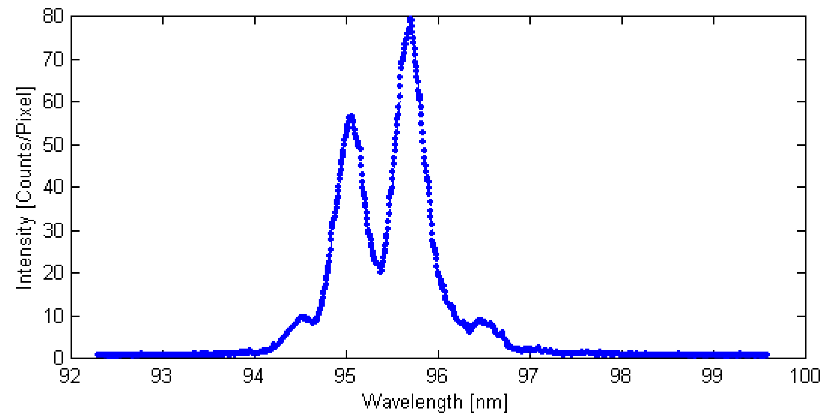
- **Controlled attenuation of FEL beam for 6-120 nm**
- **Attenuation of 10^{-6} (depending on gas)**
- **Preserve beam attributes (coherence, statistics, spectrum, etc.)**
  - changing linac parameters does not do the job

Online photon diagnostics

Experimental spectra of Phase 1

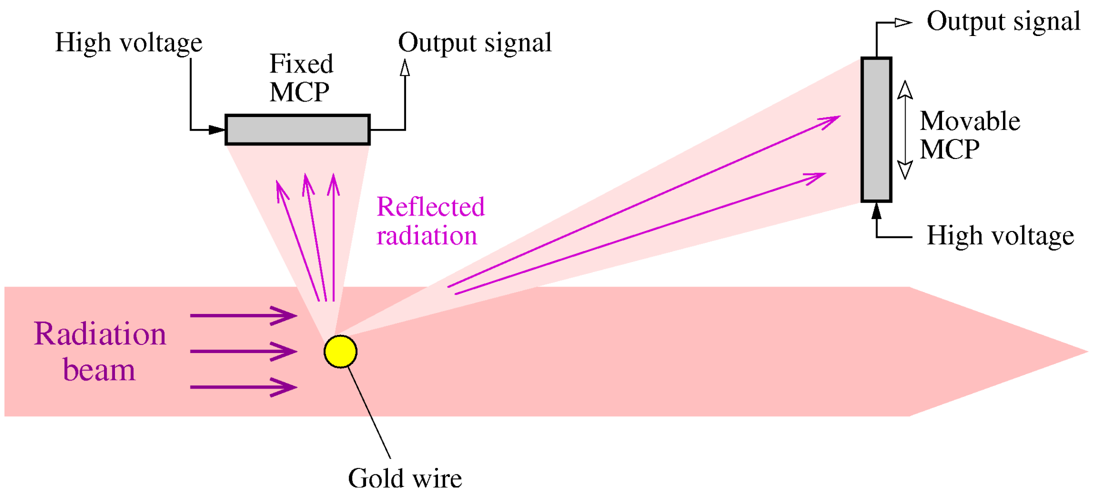
1 m normal incidence monochromator + intensified CCD camera

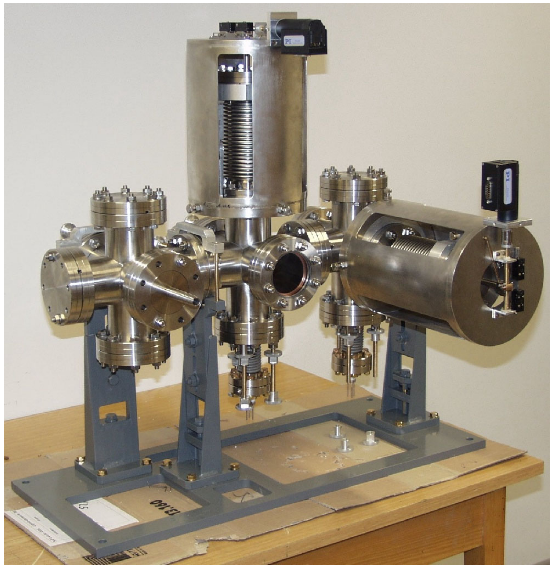




each pulse is different → **need online diagnostics with single shot resolution**

MCP Diagnostics Unit



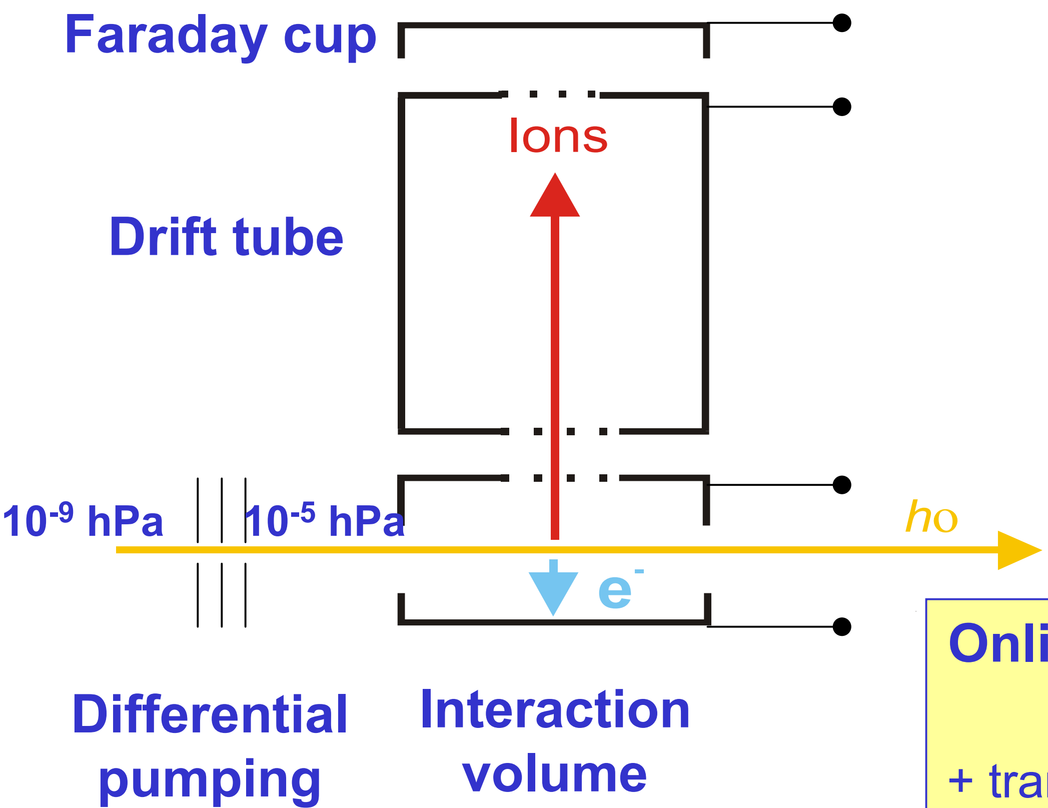


+ large dynamic range (~7 orders of magnitude)
+ can be scanned to measure beam position and profile
– sensitive to beam position
– will not survive long pulse trains
– the wire produces unwanted diffraction

ideal for FEL commissioning

A. Fateev et al., Dubna

Gas ionisation detector



Single photoionisation:

$$N = N_{ph} \times n \times \sigma \times l$$

N = number of electrons or ions
N_{ph} = number of photons
n = target density
σ = photoionisation cross section
l = length of interaction volume

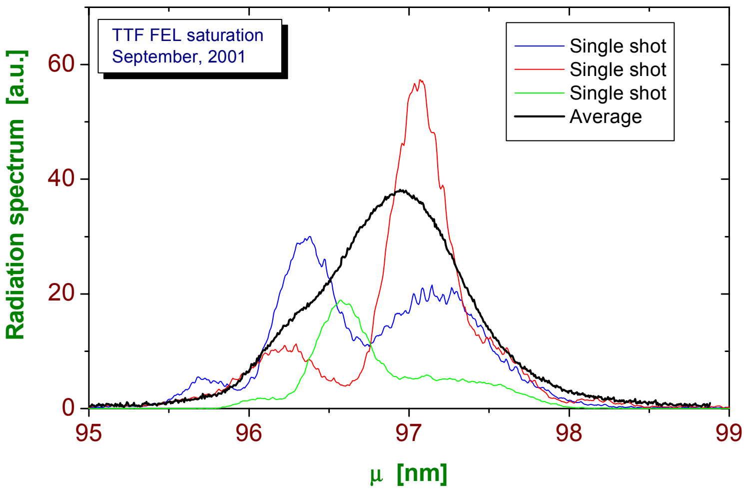
Online monitor of single-pulse FEL intensity

+ transparent
+ wide dynamic range (spont. to sat.)
+ independent of beam position
+ can measure beam position
+ no saturation effects
+ 6 nm < µ < 93 nm
+ absolute calibration (~15%)

successfully tested at Phase 1

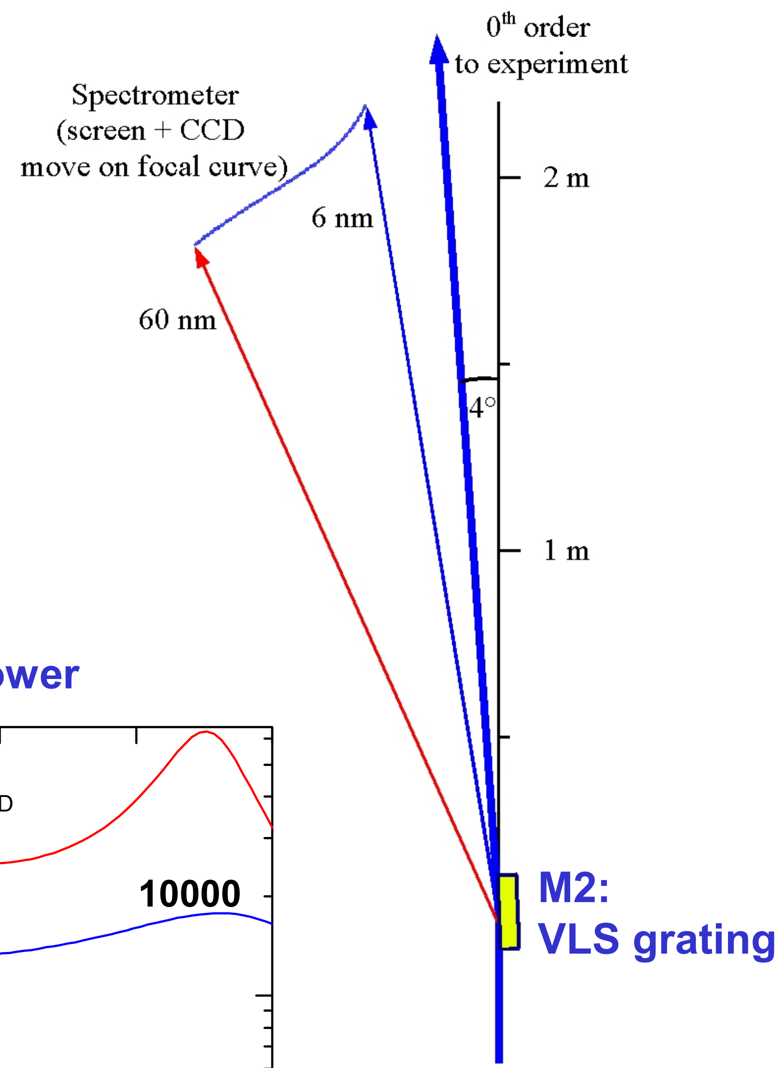
Collaboration with PTB, Berlin, and Ioffe Institute, St. Petersburg

Online spectrometer for single pulses

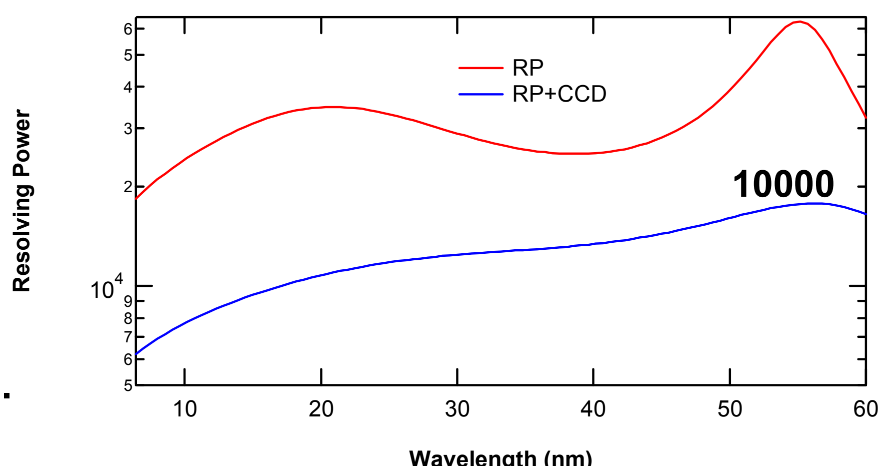


Radiation pulse length υ_{rad}:

υ_{rad} A $2\theta^{1/2}/(E\xi)_{FWHM}$ A 40 fs



Resolving power

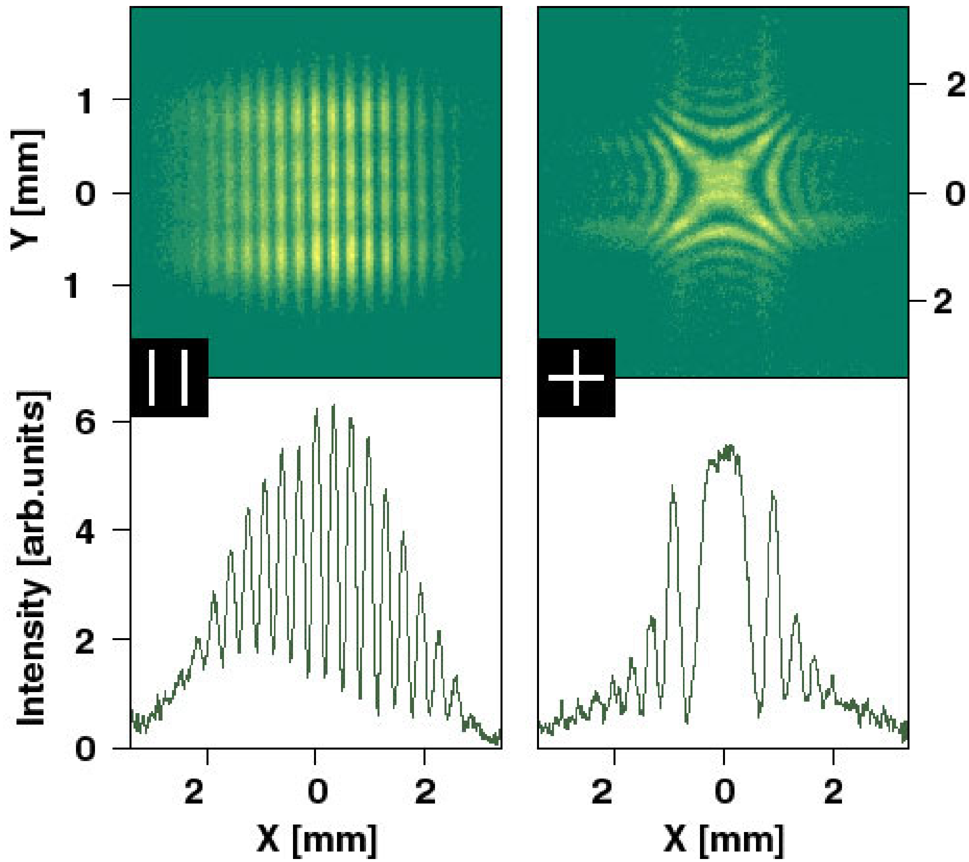


collaboration with:
R. Reininger (SAS),
F. Quinn (CLRC) et al.

Transverse coherence

Diffraction pattern of 95nm FEL radiation observed by a CCD camera on a Ce:YAG crystal 3m behind the slits (near zone)

parallel slits,
each 2mm long,
200µm wide
separation 1mm



crossed slits,
100µm wide,
4mm long

Conclusions

- The basic techniques for FEL beam distribution and diagnostics are available
  ⇒!There is no doubt that we can start user experiments when the first stable FEL beam is delivered by the machine
- More R&D is needed to
  - improve and optimise beam delivery
  - improve online diagnostics
  - improve synchronisation of optical lasers and provide exact timing signal
  - measure temporal pulse structure directly in time domain
- These developments should be driven by the user experiments

End