# 3D ellipsoid beams for a better performance of a high brightness photoinjector

- Introduction and motivation
- Beam dynamics optimization at PITZ (Germany)
- 3D ellipsoidal laser shaping (Russia)
- Summary and outlook

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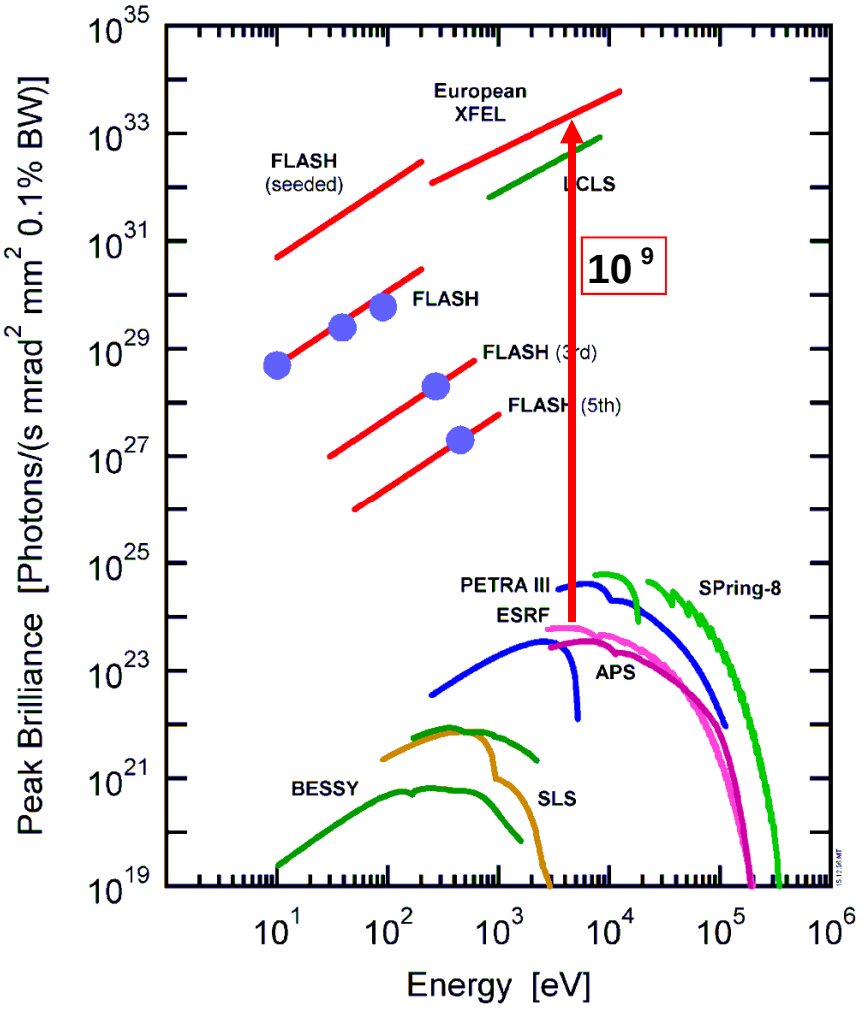
HELMHOLTZ ASSOCIATION

PITZ Photo Injector Test Facility Zeuthen

ИПФ РАН

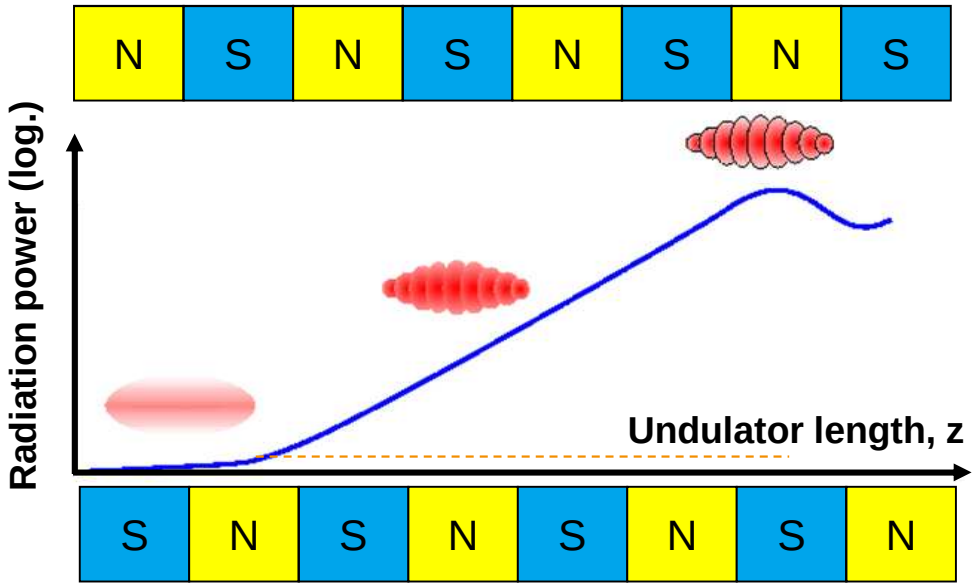
DESY

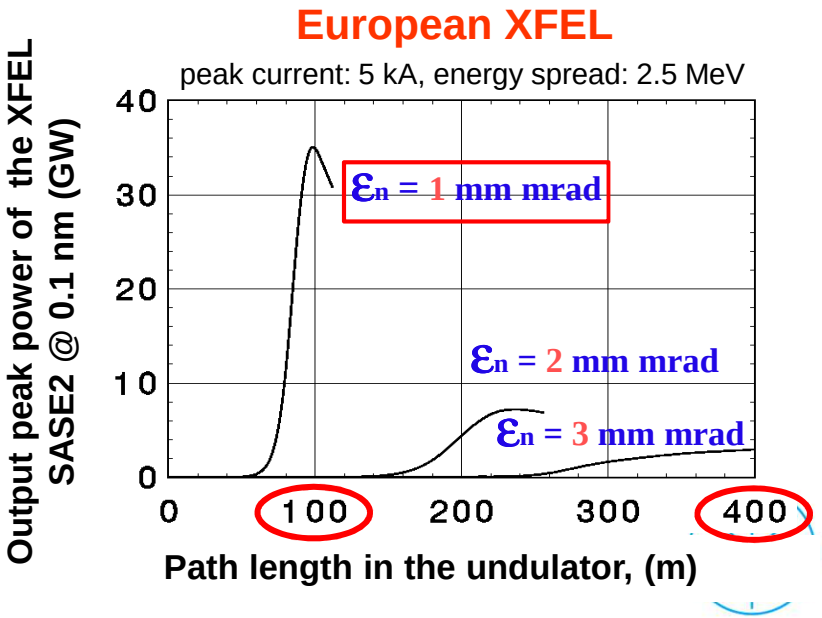
# Next generation light sources and e-beam requirements




Synchrotrons: $p \sim N \cdot e^2$

FELs (coherence): $p \sim (\mathrm{N} \cdot \mathrm{e})^2$



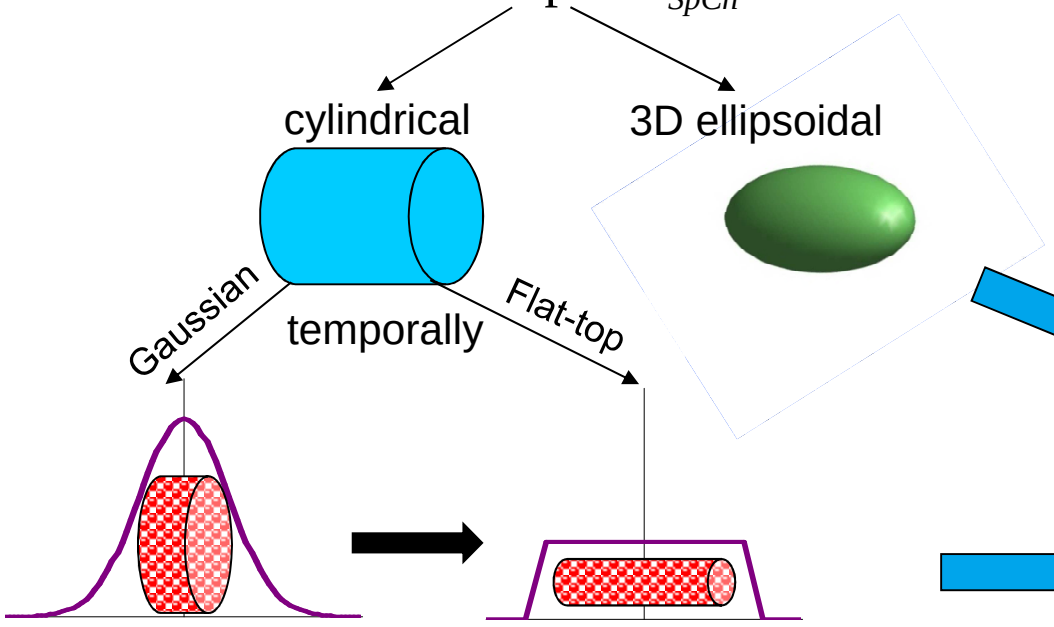



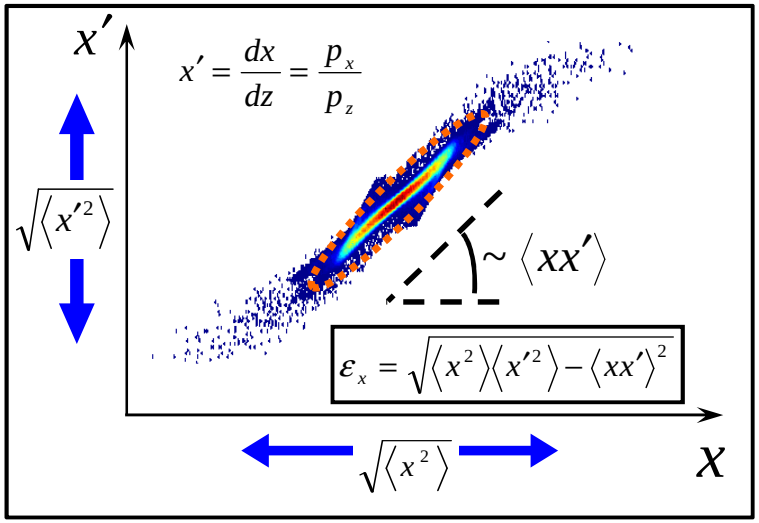
# Introduction

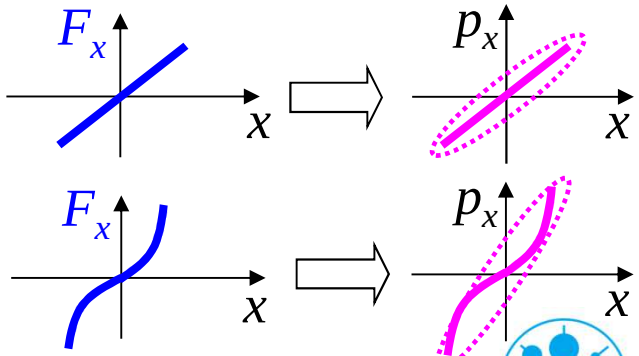
- **Motivation:** further improvement of the electron beam quality - reduction of the transverse projected beam emittance from the photo injector
- **Main idea:** optimization of the cathode laser pulse shape in order to minimize an impact of the space charge on the transverse phase space

$$\varepsilon = \sqrt{\varepsilon_{cath}^2 + \varepsilon_{RF}^2 + \varepsilon_{SpCh}^2}$$

$$\text{cathode laser shape} : \varepsilon_{SpCh} \rightarrow \min$$

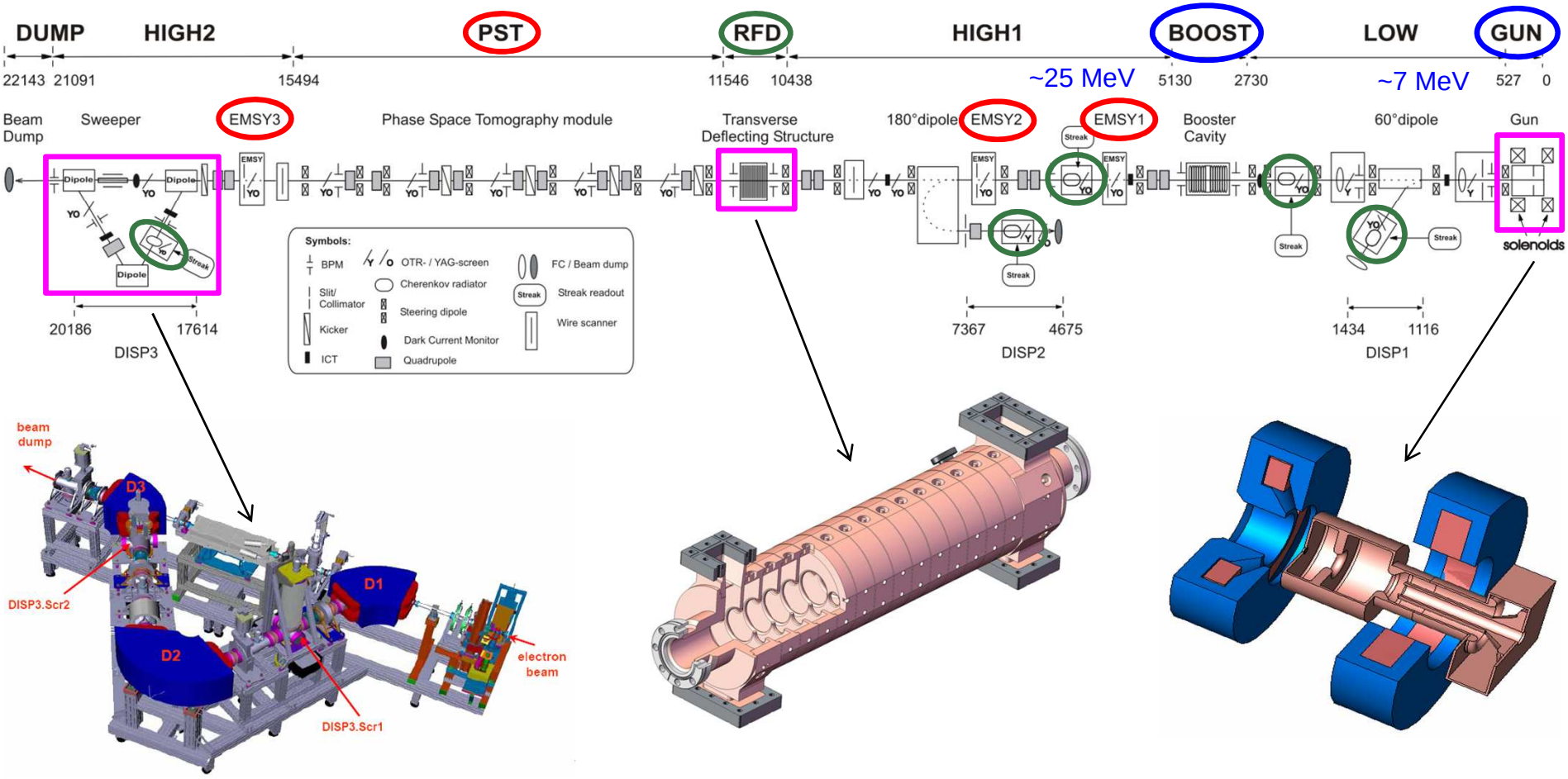


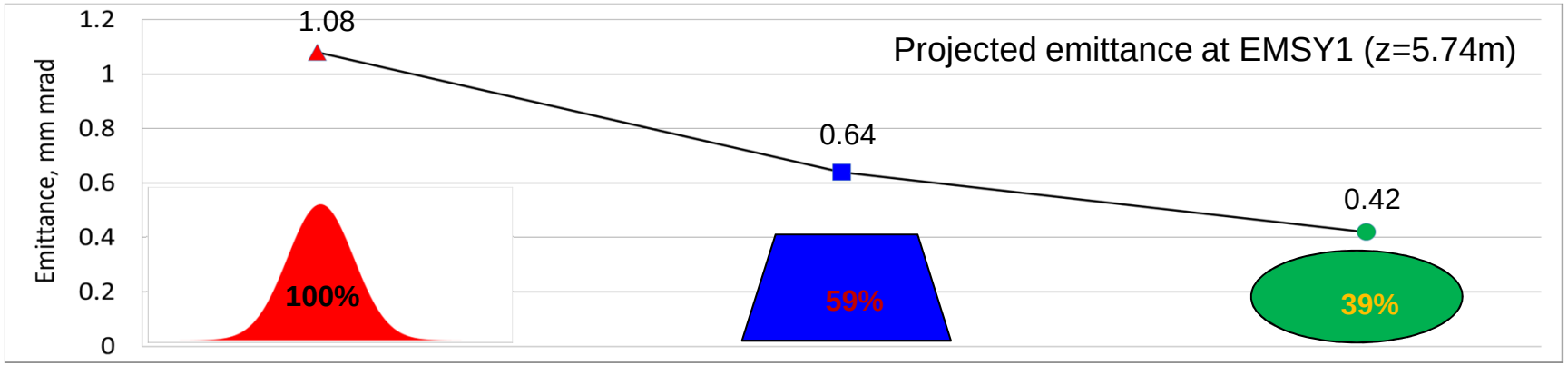
# PITZ setup : overview

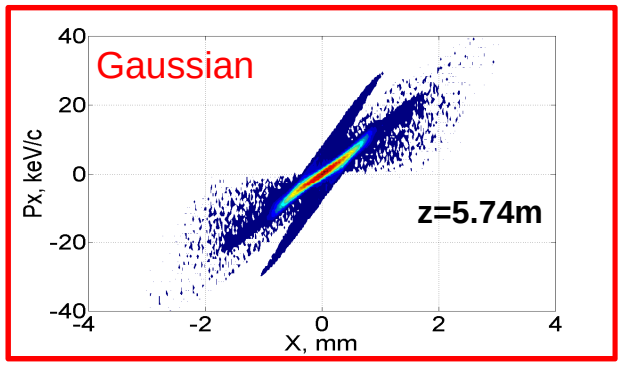
Diagnostics for measuring the transverse and longitudinal beam properties

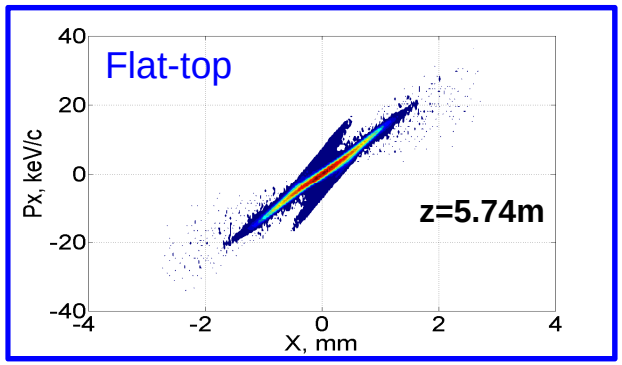


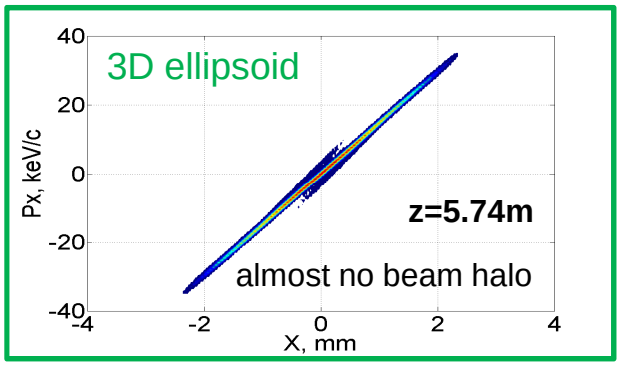

**PITZ has already demonstrated the beam requirements of European XFEL !**

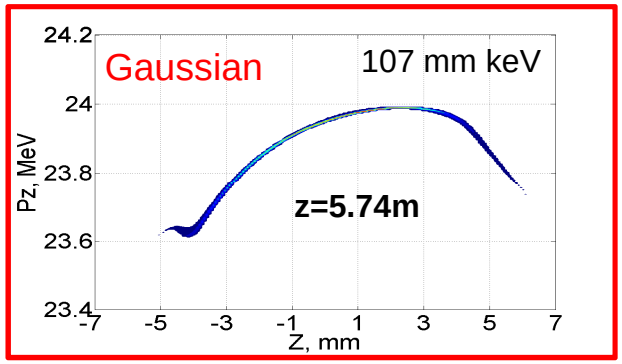
# Optimum temporal laser shape for the best emittance

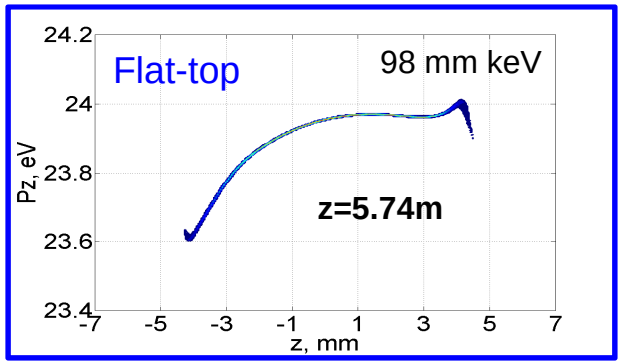


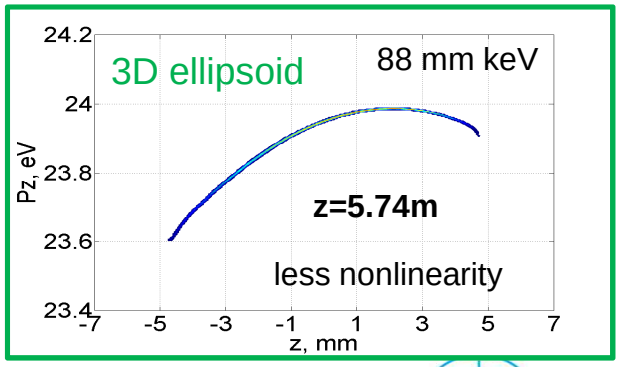



# Practical realization of the BMBF-Project 05K10CHE

> Collaboration: **DESY** (Germany) – **JINR** (Dubna, Russia) – **IAP** (Nizhny Novgorod, Russia)

> Goal – develop the photo cathode laser system with the following parameters:

| parameter | value | unit | remark |
|---|---|---|---|
| wavelength | 258 | nm | 1030 nm fundamental λ |
| micropulse energy | 15 | μJ | for 1 nC bunch production from $Cs_2Te$ photo cathodes |
| pulse train frequency | 1 | MHz | In the future 4.5 MHz will be a goal |
| pulse train length | 0.3 | ms | In the future 0.6 ms will be a goal |
| pulse train rep. rate | 10 | Hz | 1,2,5 Hz as an option |
| micropulse rms duration | 6±2 | ps | 3D quasi ellipsoidal distribution |
| transverse rms size | 0.5±0.25 | mm | |

**The work is funded by the German Federal Ministry of education and Research (BMBF) project 05K10CHE "Development and experimental test of a laser system for producing quasi 3D ellipsoidal laser pulses" in the framework of the German-Russian collaboration "Development and Use of Accelerator-Based Photon Sources".**

two major components were purchased in Germany and shipped to Russia:

- 2x Spatial Light Modulators (SLMs, Holoeye Photonics AG)
- Diode Pump (LaserLine)



# Summary

- Photocathode laser pulse shaping is a key issue for the photo injector optimization
- Beam dynamics simulations applying 3D pulse shaping (ellipsoid) yield to:

  Significant reduction in beam projected emittance (more than 30%) compared to the optimized flat-top laser profile

  (~ same beam current)
- Advanced 3D shaping of the cathode laser pulse:
- Expected advantages:

  Reduced projected and slice emittance (higher beam brightness)

  More regular shape in longitudinal phase space (better beam longitudinal compression)
- Practical realization → developments at IAP (Nizhny Novgorod, Russia):

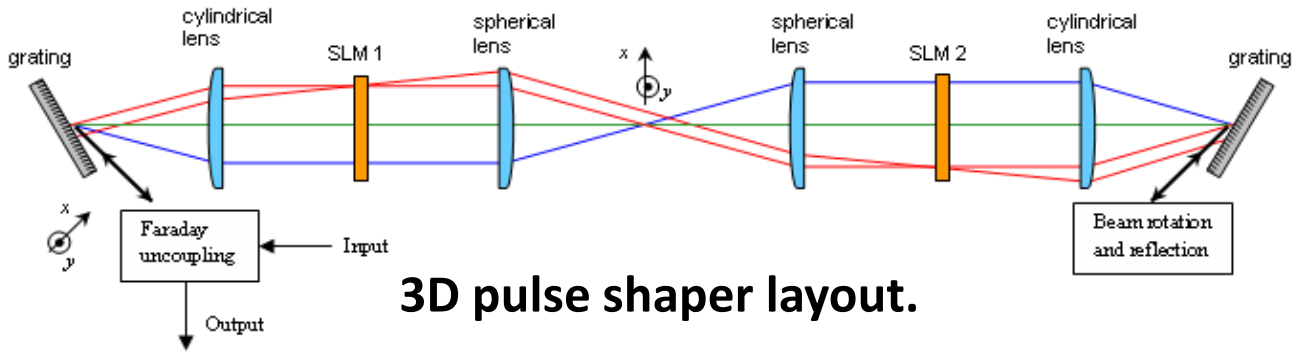
  First test measurements have been performed → the results still to be improved
- The project (05K10CHE) to realize quasi 3D ellipsoidal laser shape is ongoing. The advanced laser system might be placed at PITZ within the next year

Thank you for your attention !!

# New photocathode laser system under development at IAP (Nizhny Novgorod, Russia):

1. Fiber oscillator and preamplifier → ~1uJ and chirped 100ps pulses (200fs Fourier transform limit) in both channels (working and diagnostic), grating compressors
2. Solid state amplifiers based on Yb:KGW water cooled thin-disk,
3. 3D-ellipsoidal pulse shaper based on two liquid crystal Spatial Light Modulators (SLM)
4. Solid state amplifiers based on Yb:KGW water cooled thin-disk, the multi-pass amplifier should work without dramatic distortion of the pulse shape
5. 2nd and 4th harmonics generation in thin LBO and BBO crystals utilizing the angular chirp technique to achieve high efficiency of conversion without shape degradation.

The proposed 3D-ellipsoidal **pulse shaper** consists of two 2D-SLM's (one for amplitude and one for phase masking) installed inside the zero-order compressor. Double pass of the setup supplemented with a 90deg image rotation between passes provides successive access to (X-frequency) and (Y-frequency) planes respectively. Since the pulse shaping technique with SLM's is available only on the fundamental wavelength it is necessary to preserve the pulse shape during the amplification and harmonic generation.




**3D pulse shaper layout.**