Upgrade laser SPARC

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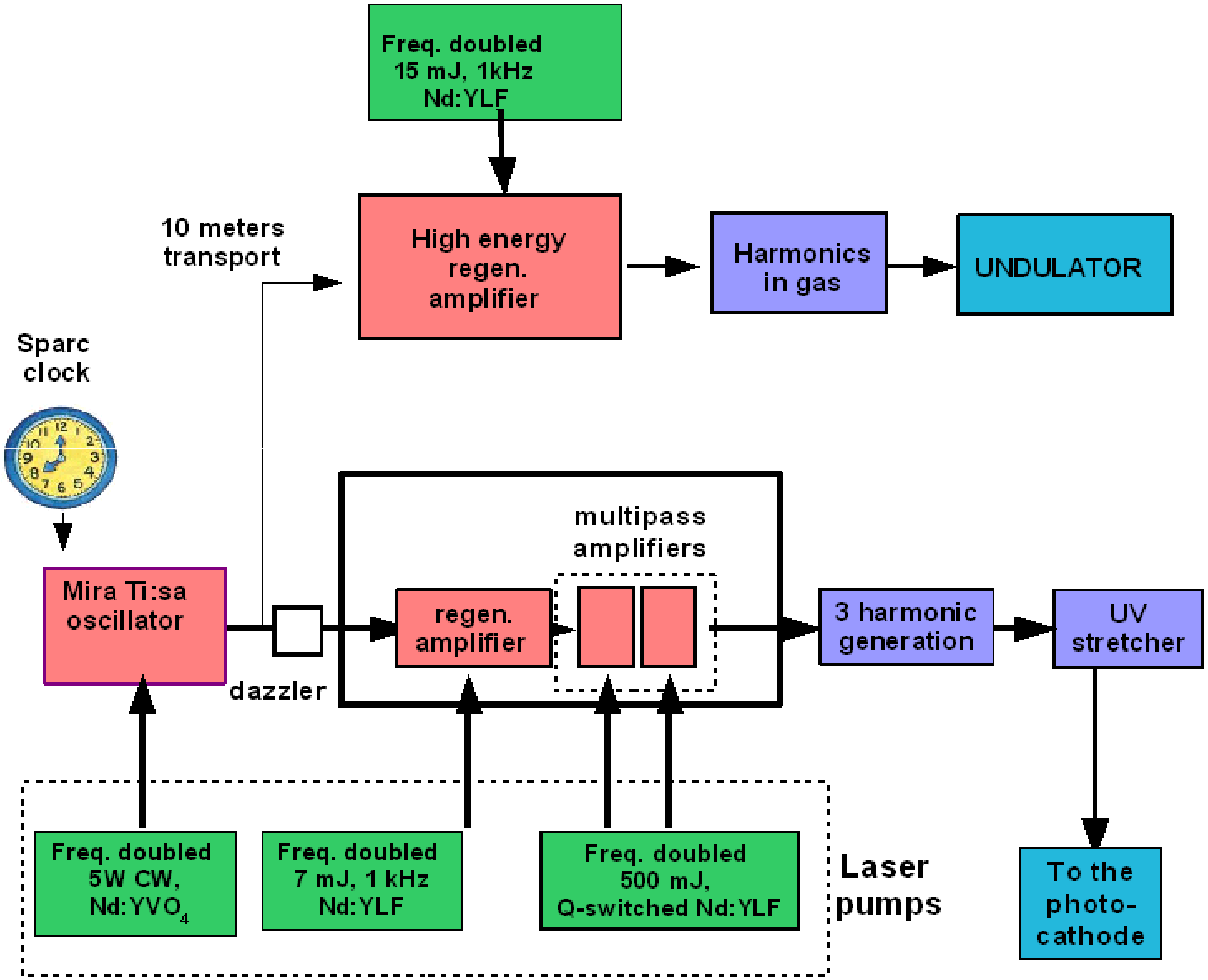
Outlines

- Description of photocathode drive laser for SPARC
- Specifications and recorded performances
- Control of the time pulse shape
  - Flat top
  - Multipeaks
  - Modulated pulse
- Improvements towards user facility photocathode drive laser

Photocathode drive laser

- The photoemitted electrons are directly controlled by the 3D photons distribution of the drive laser
- The photocathode drive laser is used to produce high current + low emittance electron beam
- The SPARC laser has to deliver 5-12 ps, 300 uJ pulses at 266 nm with a rep. rate of 10 Hz.
- To minimize the emittance:
  - **a flat time profile** with < 2 ps rise-time is required.
  - **uniform spot** at the cathode with radius between 0.2 – 1.1 mm.
- Low energy jitter (5% rms), pointing stability (<50 mm) and synchronization reapect to the RF (<2ps rms) are also important.
- The laser can be also used for e-beam diagnostic and to trigger experimental apparatus

SPARC laser system

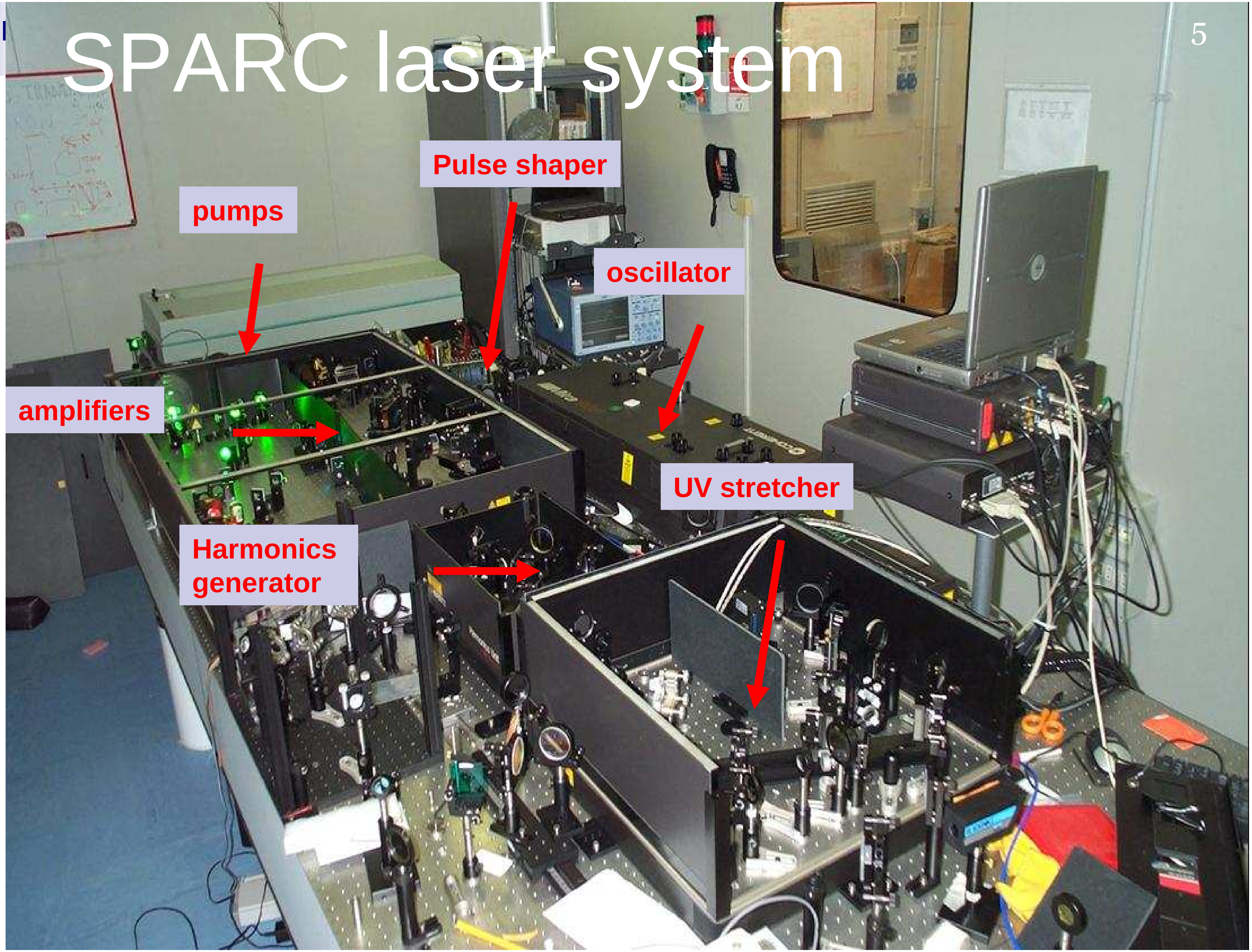


Ti:Sa laser

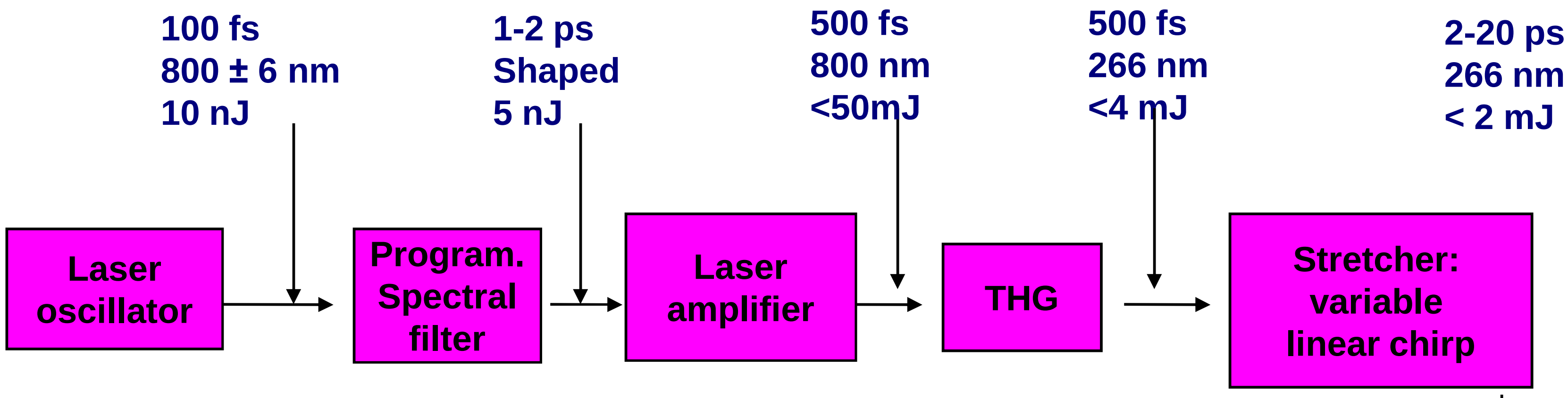
- Operation 6 days 24 h a week
- Rep rate 10 Hz
- Transport to the cathode
- A second Ti:Sa amplifier is used for the seeding experiment

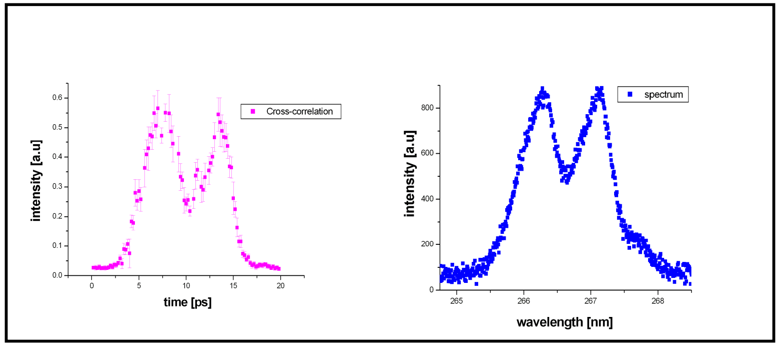
SPARC

SPARC laser system



Sparc laser system





Time profile=spect profile

$$I(t) = \left| \int \tilde{A}(\omega) \exp\left[i \left(\frac{\alpha \omega^2}{2} - \omega t \right) \right] d\omega \right|^2 \sim \tilde{I}(\omega = t/a)$$

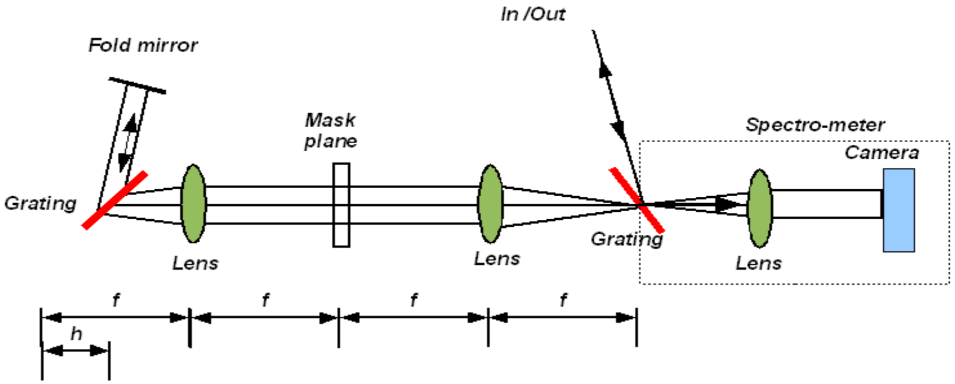
if $\alpha \cdot \Delta\omega >> 1$

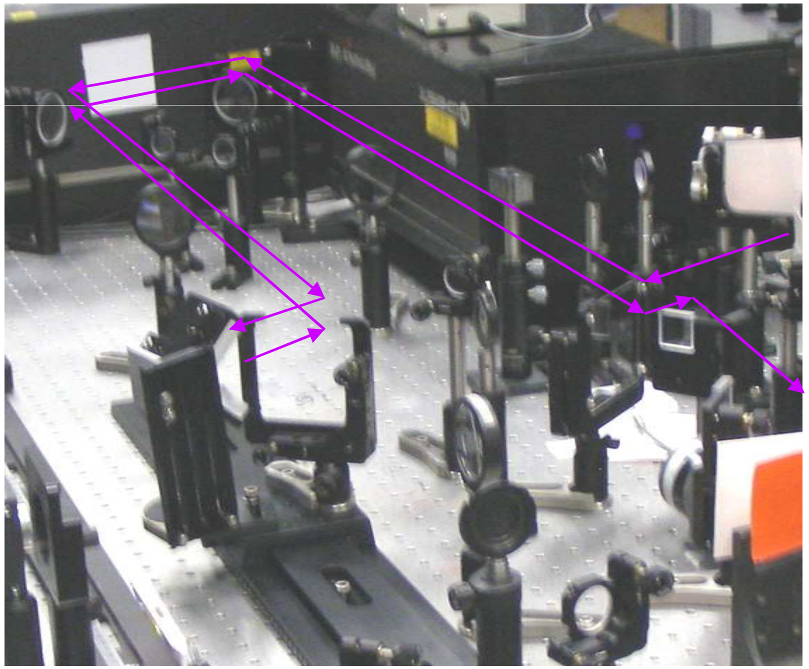
Designed custom UV stretcher

The UV stretcher designed on transmission gratings with efficiency up to 50%

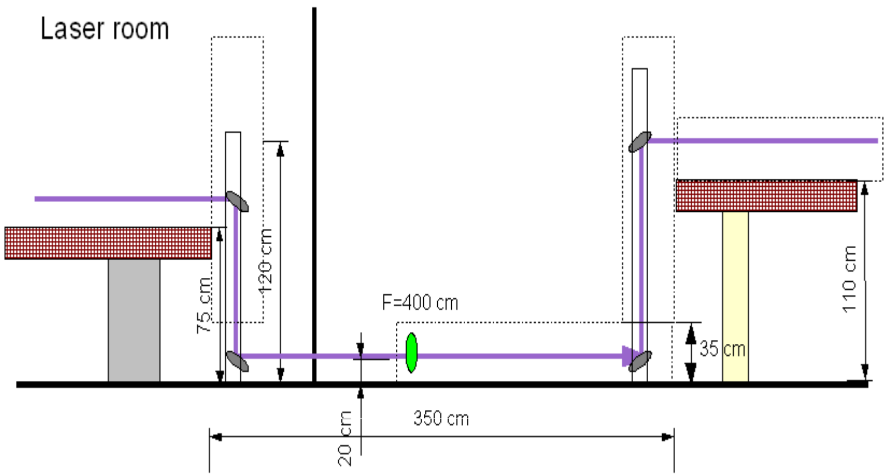
Functionalities:

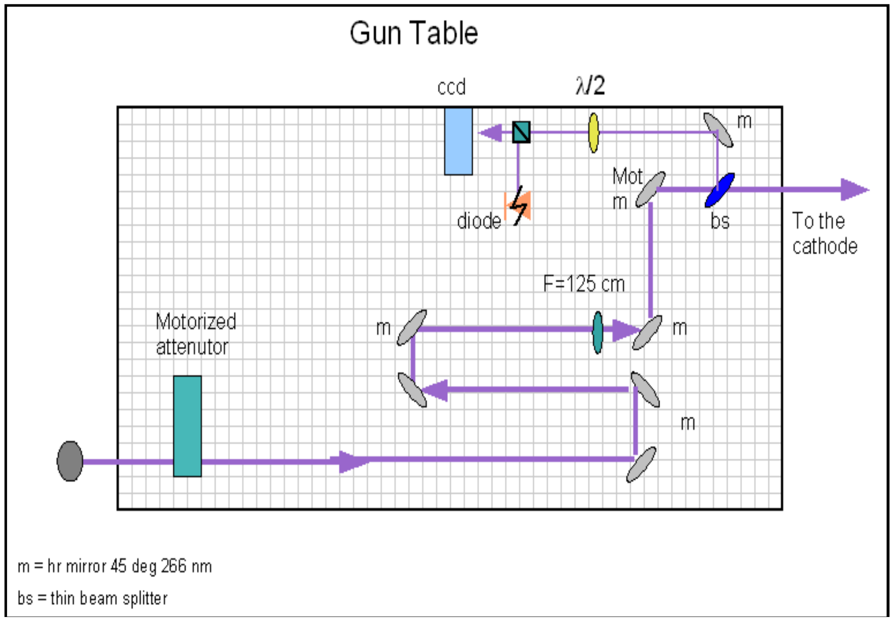
1. **Lengthen the laser pulse proportional to h up to 20 ps.**
2. **In the Fourier plane an amplitude filter can be applied to cut the tails of the spectrum. The obtained spectrum profile is projected into the time profile by the stretcher**
3. **A on-line spectrometer is integrated.**

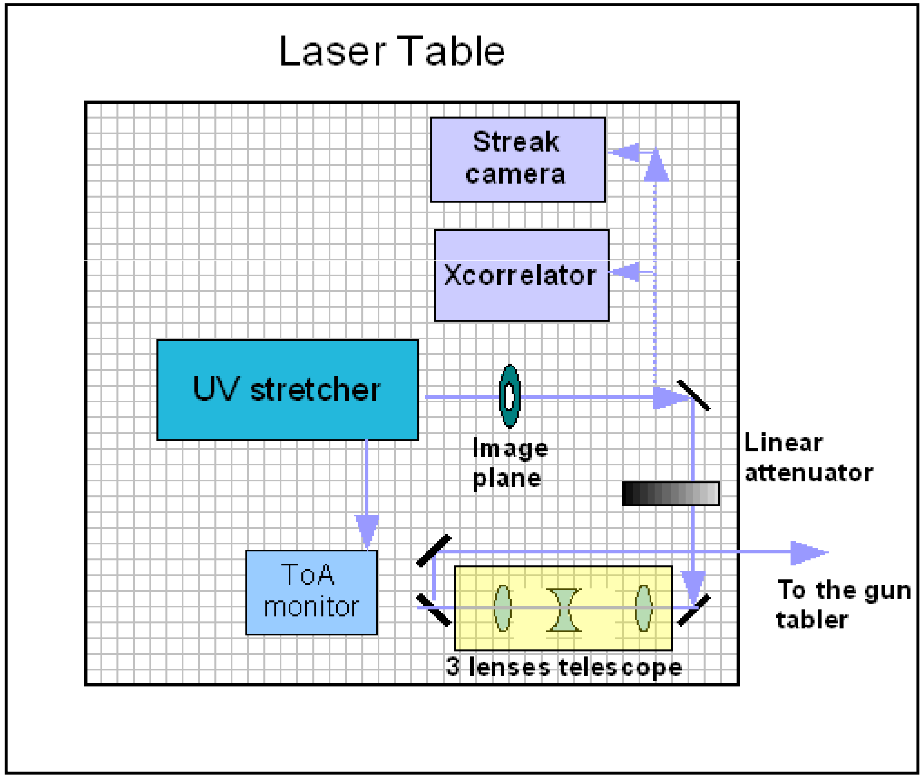




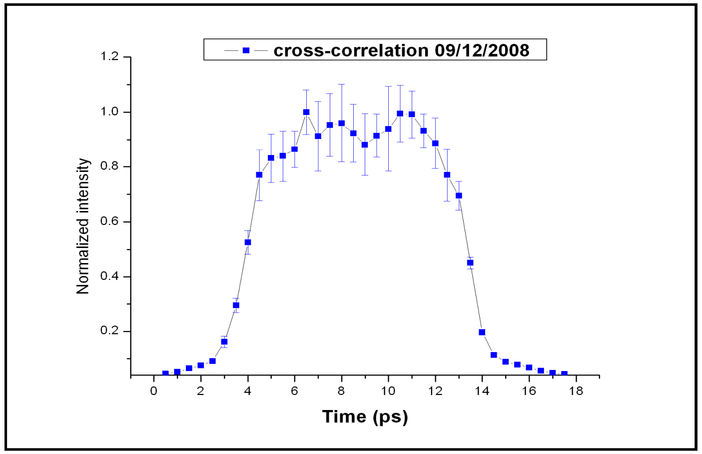
Optical transfer line

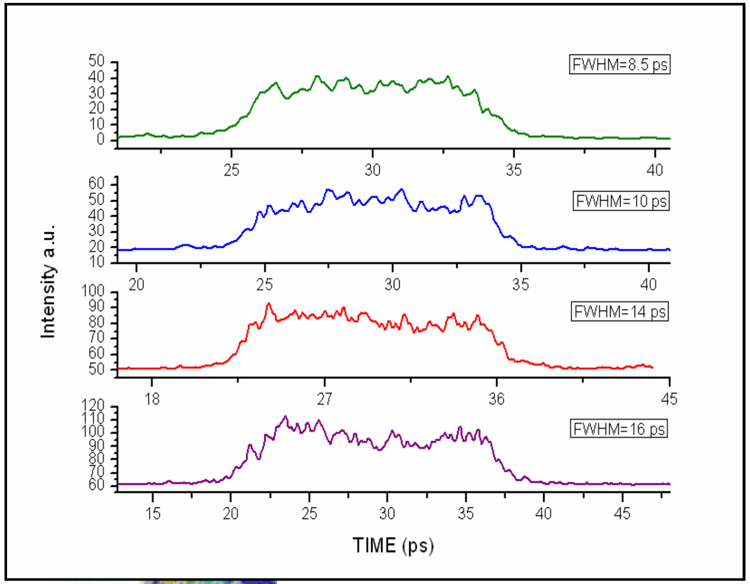


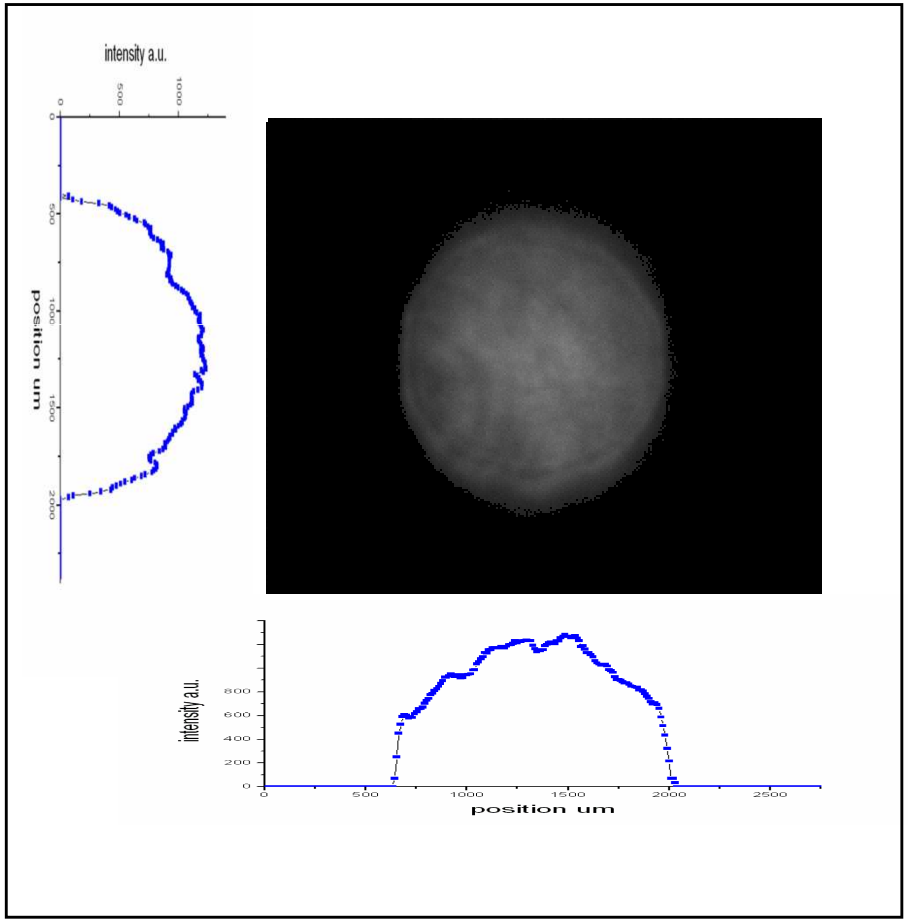




Performances: 3D shape

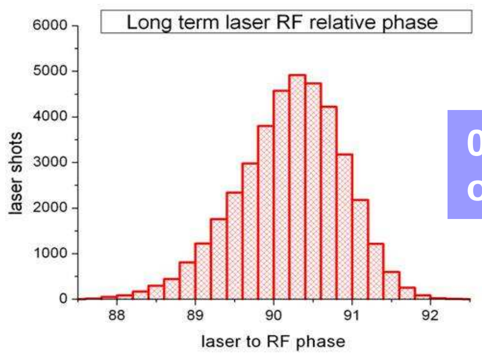






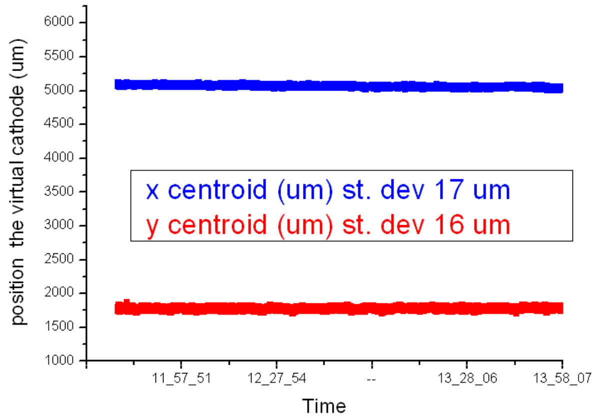
Performances

Laser to RF phase

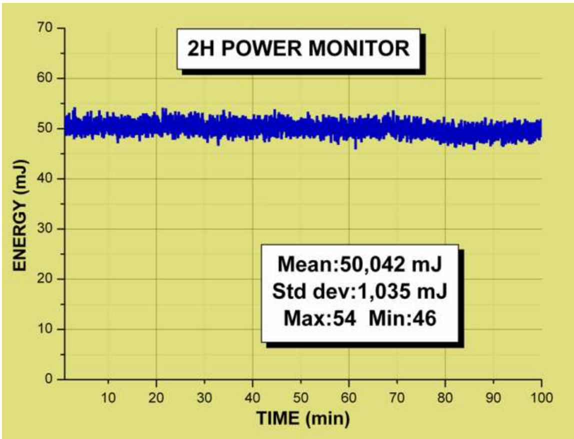


0.67 ps rms over 6 hours

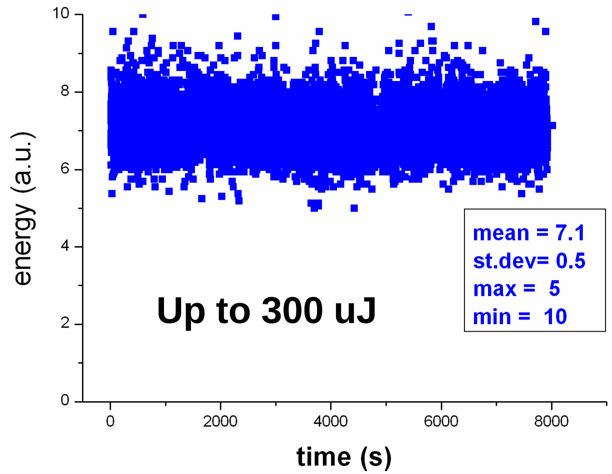
Pointing stability



IR energy stability



UV energy stability



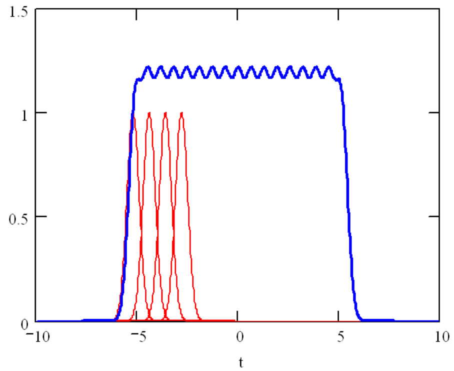
SPARC

New activities for time pulse shape

- More efficient and shorter rise time flat top pulses
- Short pulse for electro-optics diagnostics and ultrashort electron pulse (not challenging for T>200 fs laser)
- Two pulses for pump & probe experiments
- Micro-pulses (≥2) within 10 ps for multipeaks e- beam. Application: THz source and wakefield acceleration, FEL
- Modulated Gaussian or flat top laser to explore micro-bunching effects predicted by numerical simulations

SPARC

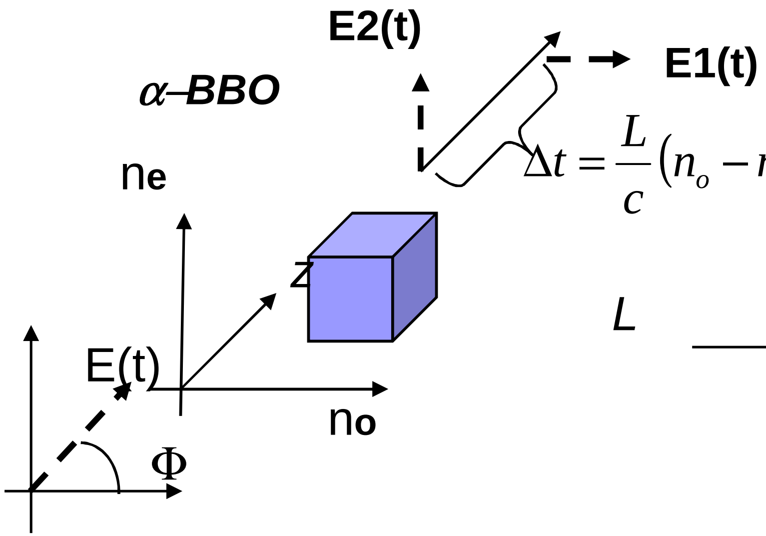
Pulse stacking



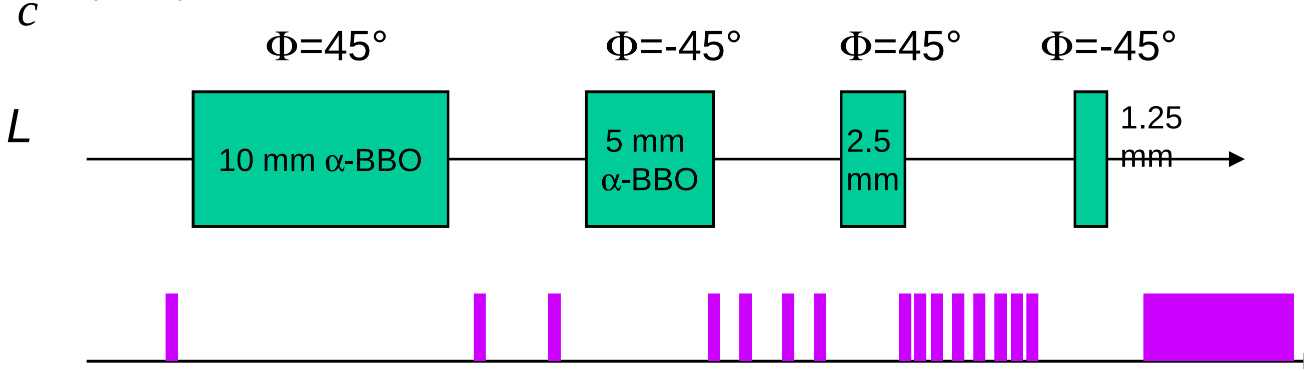
Flat top pulse can be achieved through overlapping of short UV pulse replicas delayed in time.

Birefringent crystal to split and delay

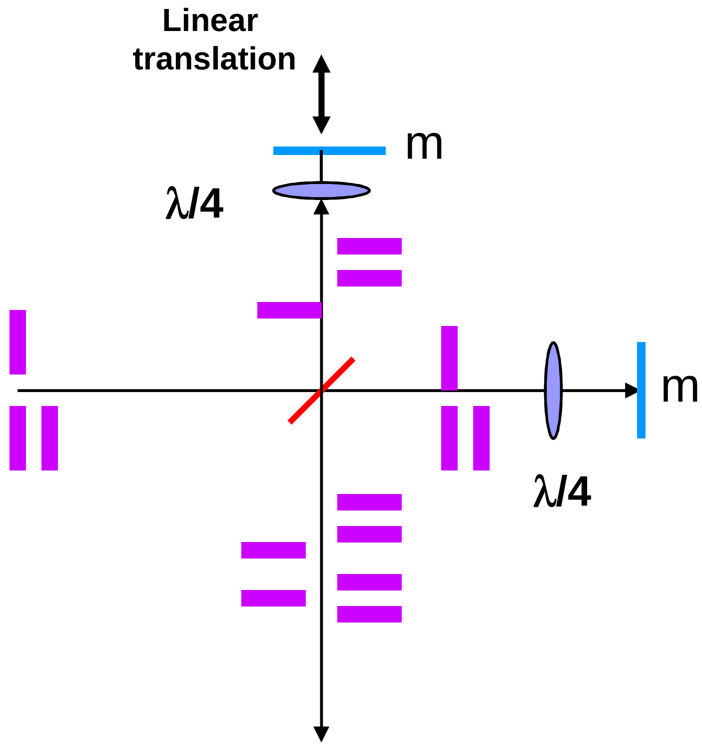
- Fixed delay is 5 ps/cm for *α–BBO*
- AR-coating (losses few %)
- multipeaks easily obtainable
- N crystals for 2^N pulses



$$\Delta t = \frac{L}{c}\left(n_o - n_e\right)$$



Multiple pulses generation



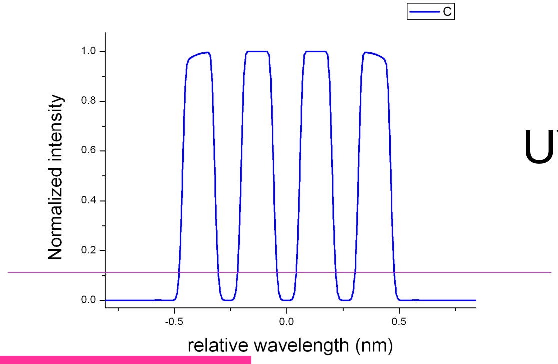
Michelson interferometer

- Ideal for two pulses
- Arbitrary pulses distance and intensity
- m interferometers cascade for 2^m pulses
- many pulses are possible but technically very difficult
- Ellipsoidal 3D shape is possible

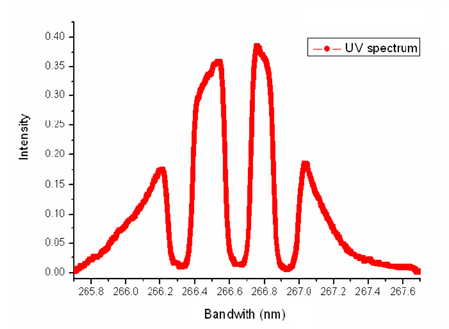
SPARC

Spectral amplitude modulation

A suitable mask in the UV stretcher can be used in order to block part of the spectrum and produce multipeaks in time

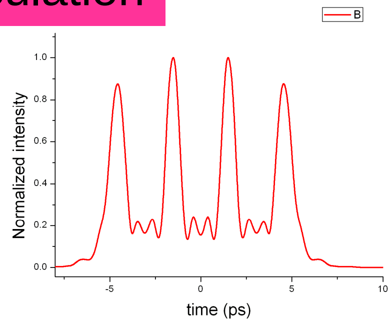


UV spectrum

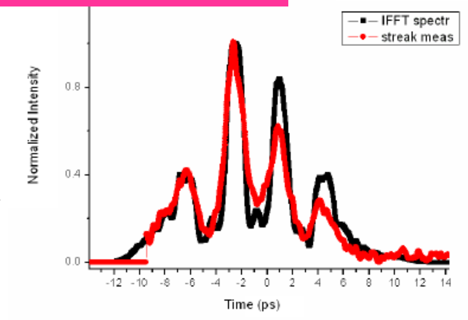


Calculation

Measurement



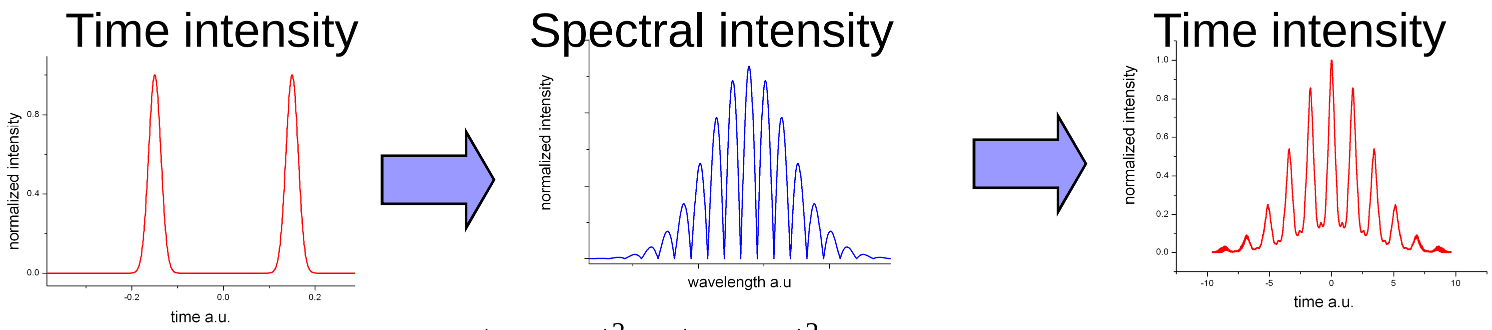
Time intensity



Limitation in number of pulses and in minimum micropulse width

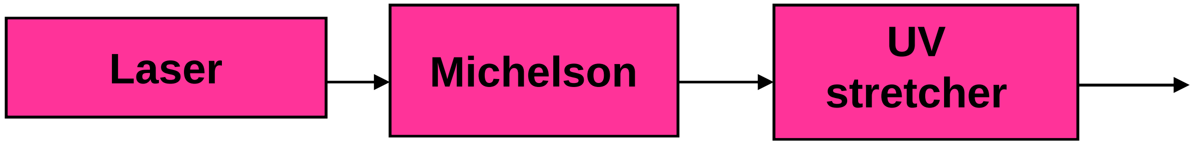
SPARC

Interference + stretching

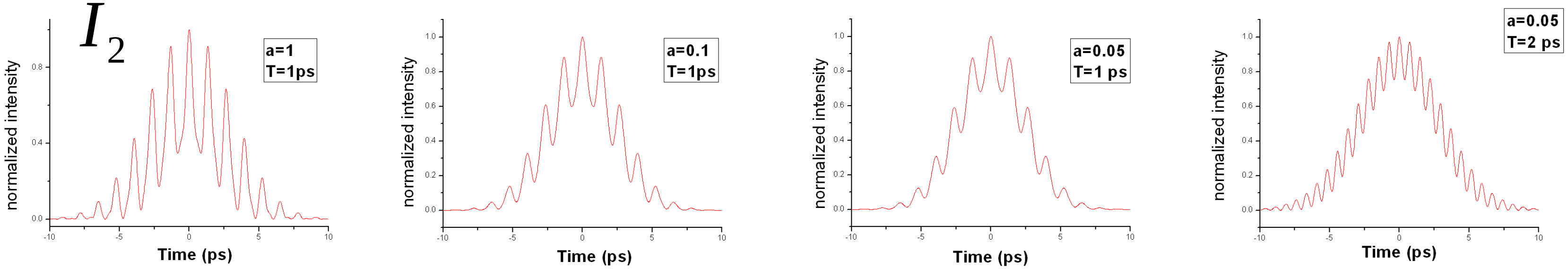


$$|S_2(\omega)|^2 \propto |S_1(\omega)|^2 \cos(\omega\tau)$$

M. Boscolo NIMA 577 (2007) 409–416



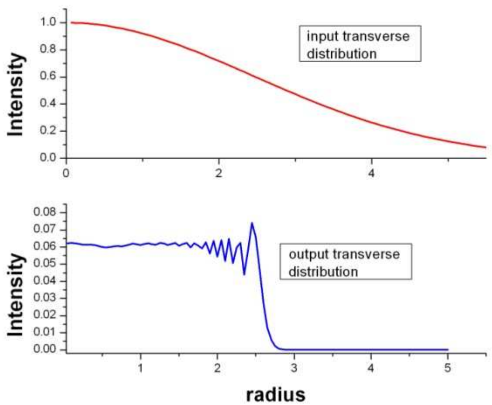
$$a = \frac{I_1}{I_2}$$

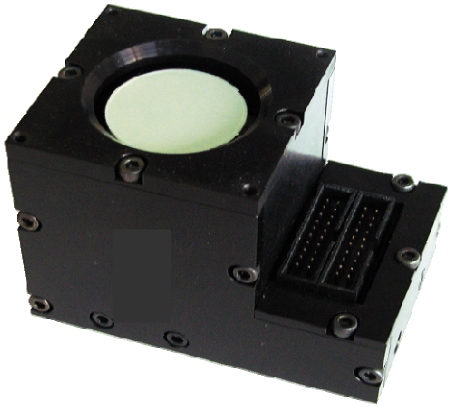


More detailed studies to understand the limits of n° pul se and single pulse length

Other improvements toward user facility operation

- Diode pumps would improve the amplitude fluctuation (<0.5% rms @ 800 nm) and the overall reliability
- The max energy would be lower but still enough
  - More efficient longitudinal shape->birefringent crystals
  - More efficient transverse shape with deformable mirror for active control of the spot at the cathode





Conclusions

- The photocathode laser system fulfills most of the requested specs
- The system demonstrated good reliability
- Further experiment to explore novel time shapes for different applications
- Improvements towards user facility photo-injector