Scheme for generation of single 100 GW 300-as pulse in the X-ray SASE FEL with the use of a few cycles optical pulse from Ti:sapphire laser system

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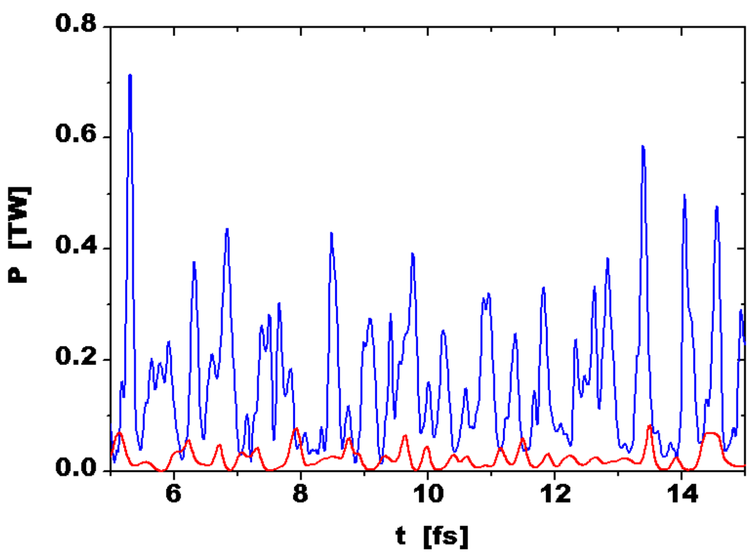
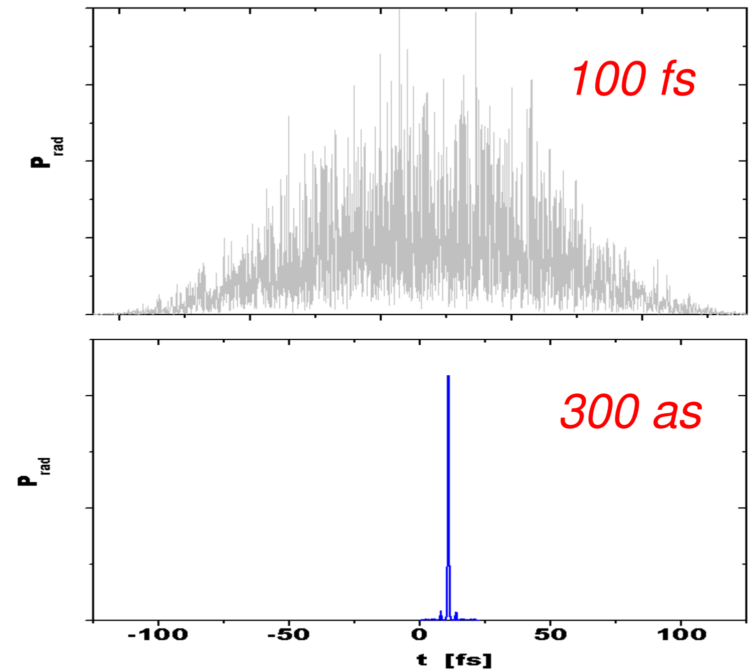
The potential for the development of XFEL beyond stdandard (SASE) mode of operation (MoPOS10-MoPOS17):



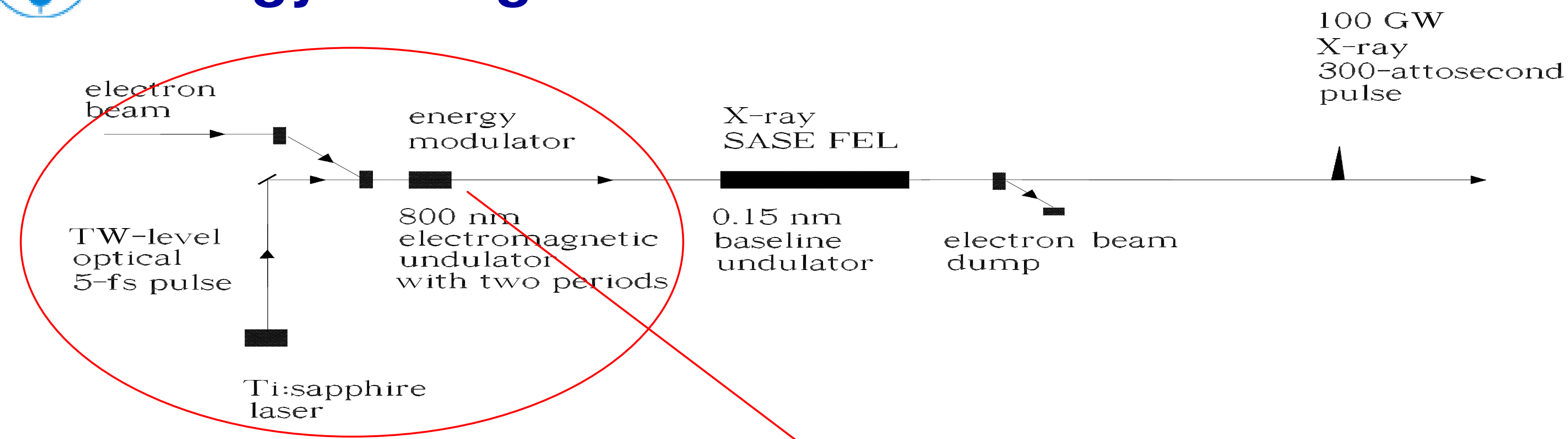
High-power (TW level) X-ray pulses



Ultrashort X-ray pulses

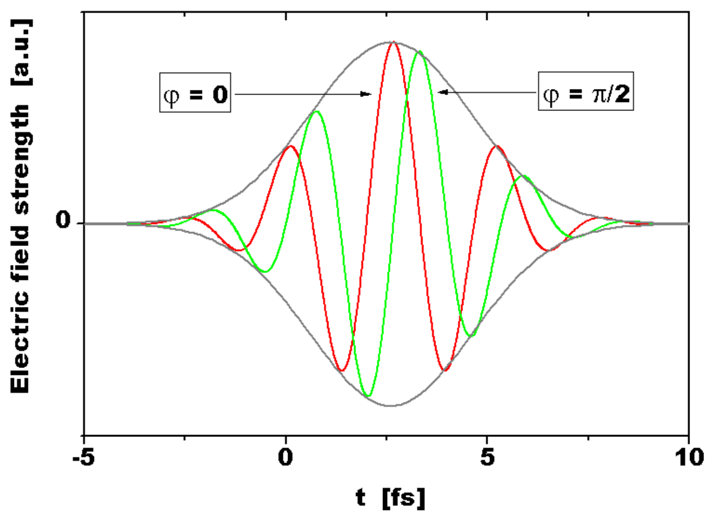
MoPOS11, ThPOS66

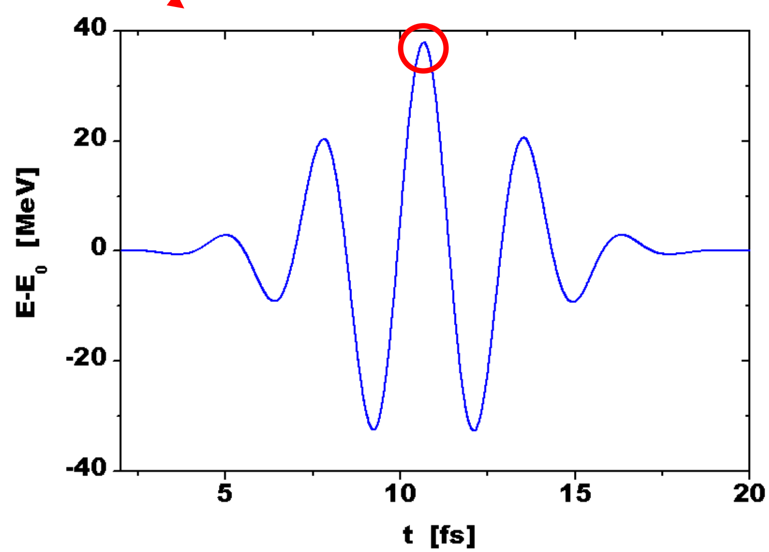
Energy slicing of the electron beam at sub-10fs scale



Laser: Ti:sapphire (800 nm)
flash energy 2-4 mJ
pulse duration 5 fs

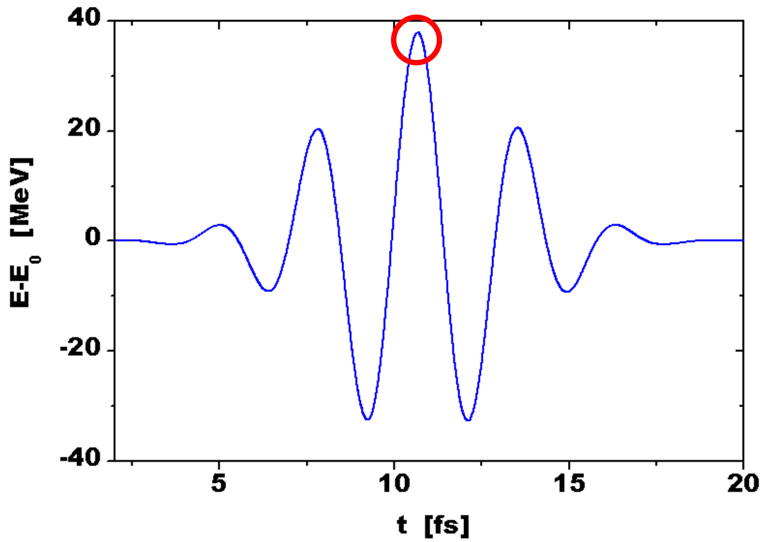
Undulator: period 50 cm
number of periods:2
peak magnetic field 1.6 T

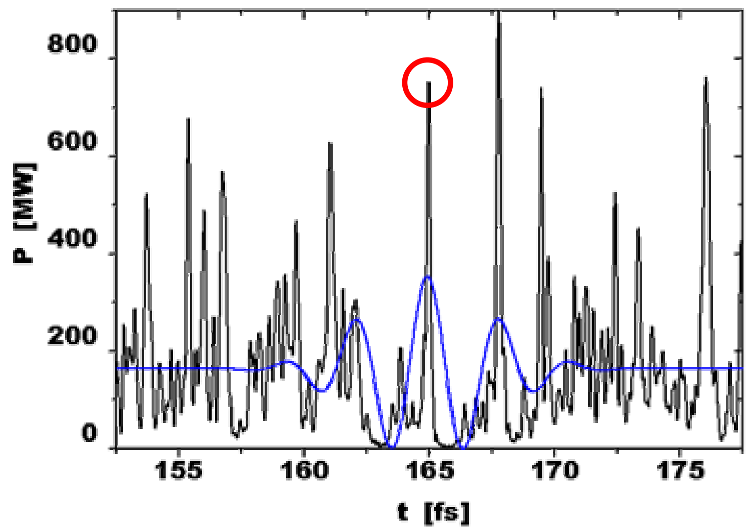




Slice energy modulation up to 40 MeV

Principle of as pulses production in X-ray SASE FEL





• The laser-driven sinusoidal energy chirp produces frequency chirp of the resonant radiation $\delta\omega/\omega$ ' $2\delta\gamma/\gamma$ correlated to the position along the bunch.

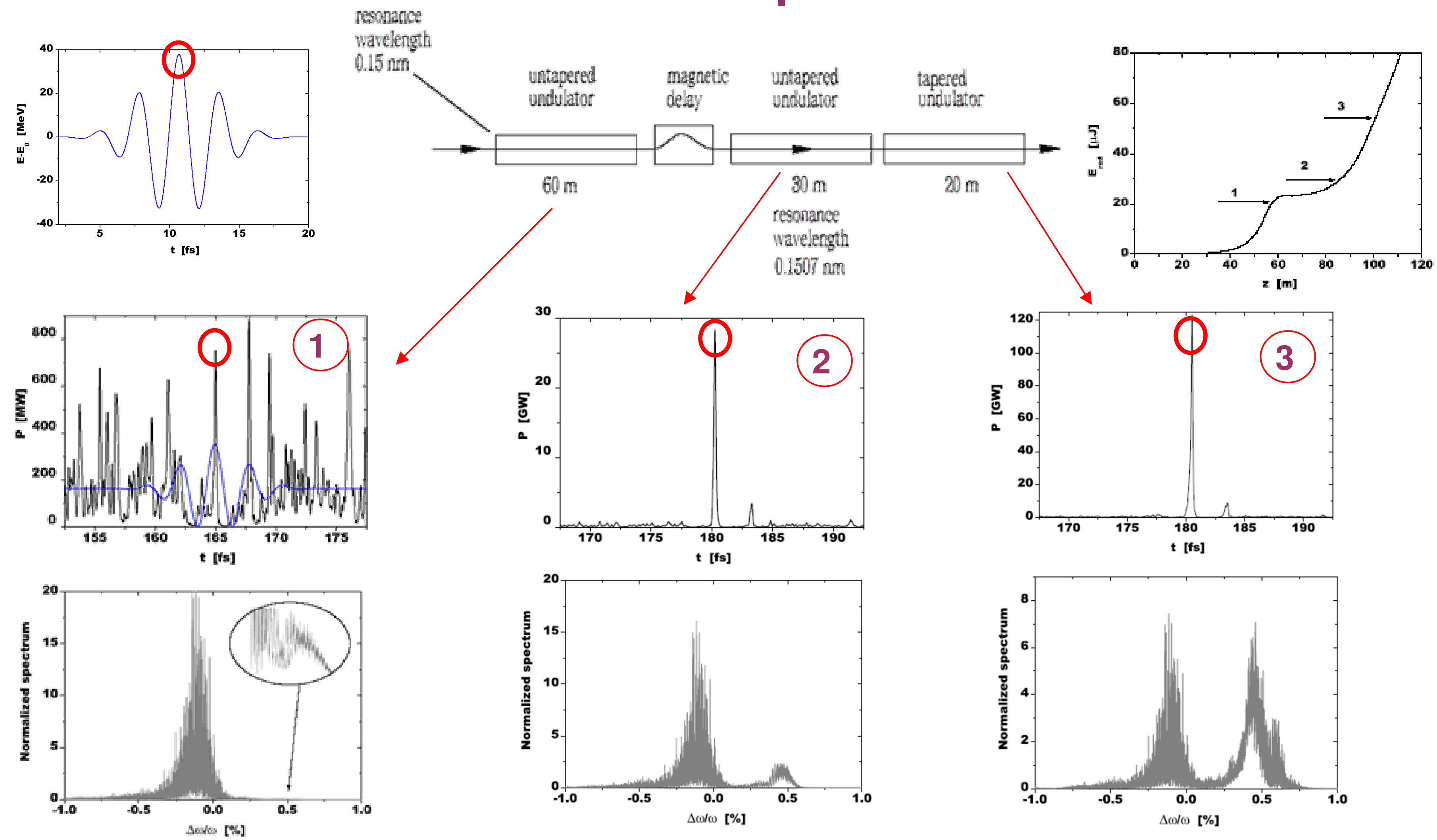
• Sensitivity of the SASE FEL process to the energy chirp along the bunch leads to effective isolation of radiative slices of the bunch.

• Selection of as pulses can be performed by:

- a crystal monochromator which reflects a narrow bandwidth ("parasitic" mode of operation);
- undulator tuned to offset frequency (dedicated 100 GW mode of operation).

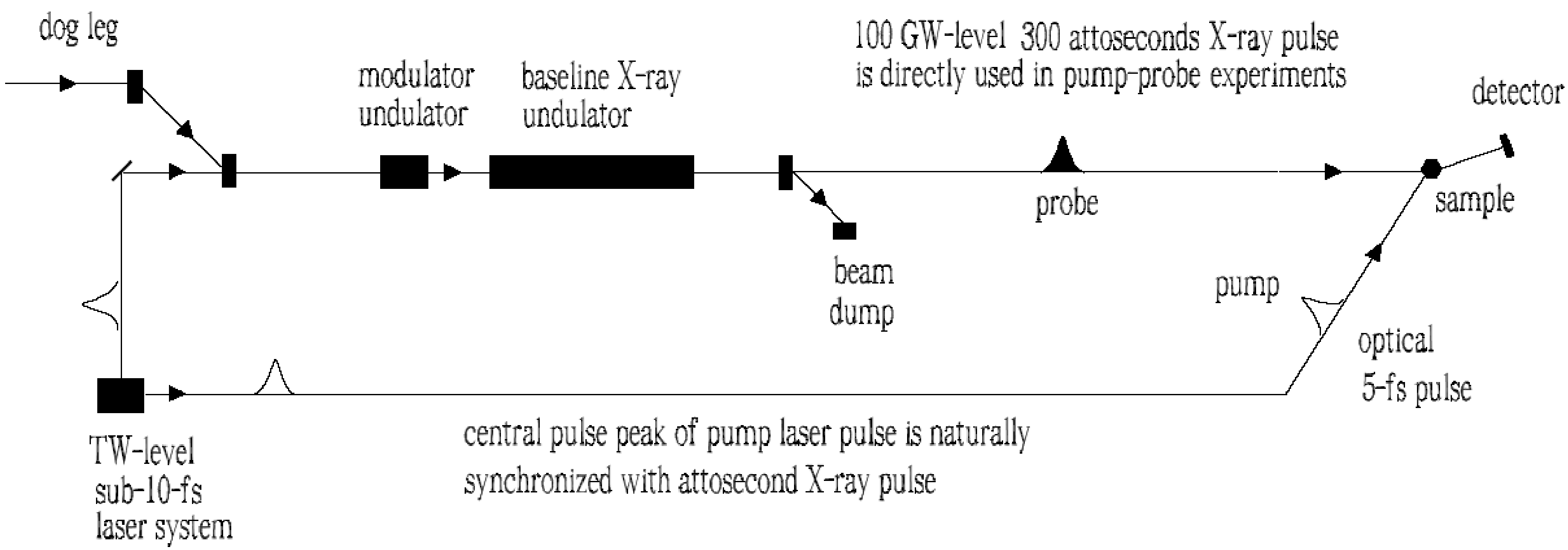
• Since the radiation frequency is correlated to the longitudinal position within the beam, a short temporal radiation pulse is extracted.

Generation of attosecond pulses in XFEL
/ 100 GW option /



- *The laser-driven sinusoidal energy chirp produces a correlated frequency chirp of the resonant radiation* $\delta\omega/\omega \simeq 2\delta\gamma/\gamma$.
- *After the first undulator the electron beam is guided through a magnetic delay which we use to position the X-ray spike with the largest frequency offset at the "fresh" part of the electron bunch.*
- *The second undulator is resonant with the offset frequency, and only a single (300 as duration) spike grows rapidly.*

Pump-probe experiments with attosecond SASE FEL



- *We suggest to combine attosecond X-ray pulses with fs optical pulses generated in the seed Ti:sapphire laser system for pump-probe experiments.*
- *Attosecond X-ray pulse is naturally synchronized with its fs optical pulse, and time jitter is cancelled.*
- *An advantage of the proposed scheme is the possibility to remove all X-ray optical elements between the X-ray source and a sample and thus to directly use the probe attosecond X-ray pulse.*
- *Usual optical elements are used for seed laser beam splitting and tunable delay. It should be possible to achieve a timing accuracy close to duration of the half period of the seed laser pulse (1 fs).*

Summary

•*Operation of attosecond option was illustrated for the European XFEL. Although the present study is concerned primarily for use in the wavelength range around 0.1 nm, its applicability is not restricted to this range, for example 0.15 nm LCLS facility is a suitable candidate for application of attosecond techniques described here.*

•*It is important that proposed attosecond scheme is based on the nominal XFEL parameters not interfering with the main mode of the XFEL operation.*

•*It can be realized with minimum additional efforts. The machine design should foresee the space for installation of modulator undulator and a viewport for input optical system.*

•*Many of the components of the required laser system can be achieved with technology which is currently being developed for applications other than the attosecond X-ray source. As a result, a laser system could be developed over the next few years and can meet the XFEL requirements well in advance of XFEL construction schedule.*

The end