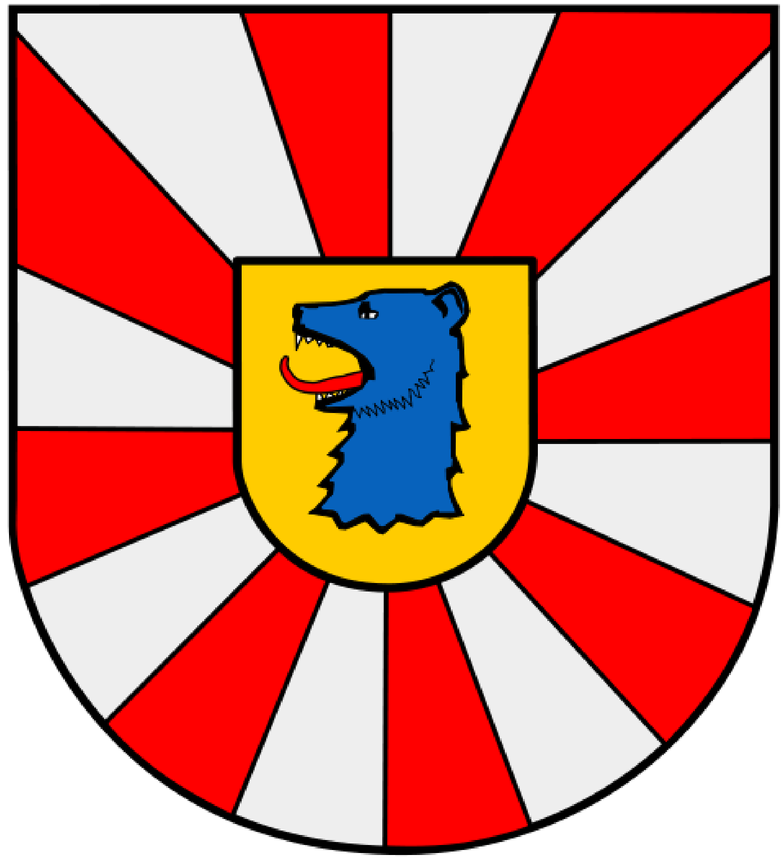
Scharbeutz [ско́ро быть]
December 7th 2016



Photon Science –
View on Future Concepts

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Zentrum für Synchrotronstrahlung (DELTA)

Photon Science

- diffraction
- spectroscopy
- imaging
- others

photons and photoelectrons
static or time resolved

Photon Science

- diffraction
- spectroscopy
- imaging
- others

photons and photoelectrons
static or time resolved

Applications outside research

- military
- industry
- medical
- home use (?)

Photon Science

- diffraction
- spectroscopy
- imaging
- others

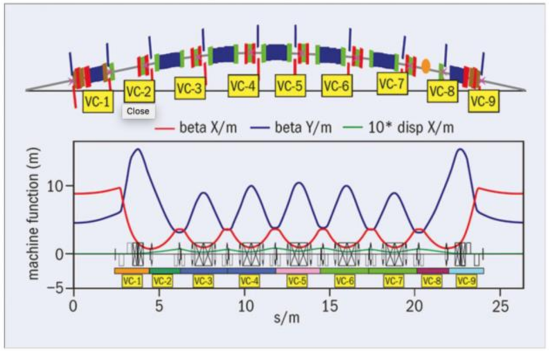
photons and photoelectrons
static or time resolved

Requirements for scientific users

- photon energy (wavelength, frequency), tunable, small bandwidth
- intensity (flux, brillance, repetition rate, ...)
- spot size, divergence (emittance)
- pulse shape and duration
- longitudinal and transverse coherence
- stability (shot-to-shot, longterm)
- availability
- access

Accelerator-based Photon Sources

(1) Incoherent emission of synchrotron radiation
ring + magnet* = synchrotron light source
linac + magnet = short-pulse facility
ERL + magnet = low-emittance/short-pulse facility
AA + magnet = compact synchrotron light source

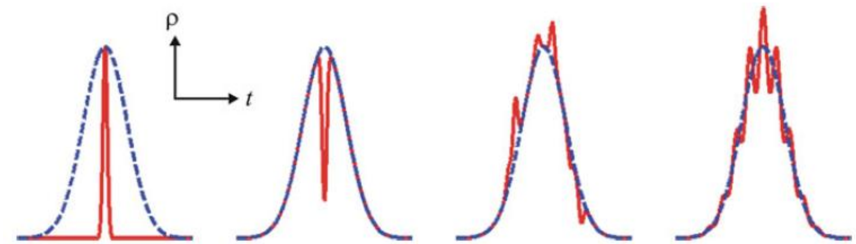


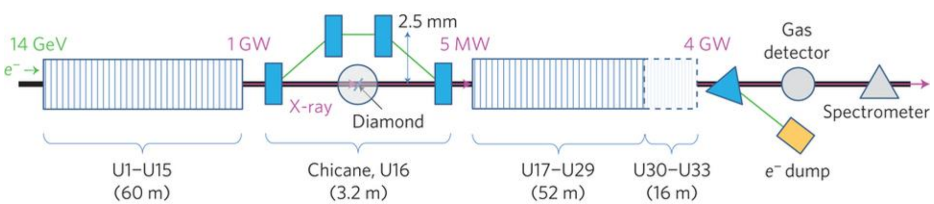
***magnet = dipole, wiggler, undulator**

Accelerator-based Photon Sources

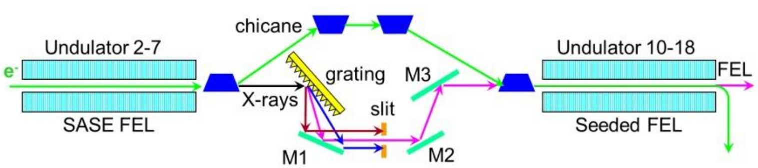
(2) Coherent emission of synchrotron radiation

ring/linac/AA + short bunch + dipole = far-IR facility
ring + microbunching (CHG, SSMB) + undulator = coherent short-pulse facility
ring/linac/ERL + FEL oscillator = IR/UV facility
linac + XFELO = X-ray laser
linac + SASE FEL = X-ray laser
linac + seeded FEL = VUV laser
linac + self-seeded FEL = VUV/X-ray laser
AA + FEL = compact VUV/X-ray laser





J. Amman et al., Nature Phot. 6 (2012), 639



D. Ratner et al., PRL 114 (2015), 504801

Accelerator-based Photon Sources

(3) Other

Compton scattering

Smith-Purcell radiation

X-ray tube

Advanced accelerators

conventional
accelerator
old-fashioned, clumsy

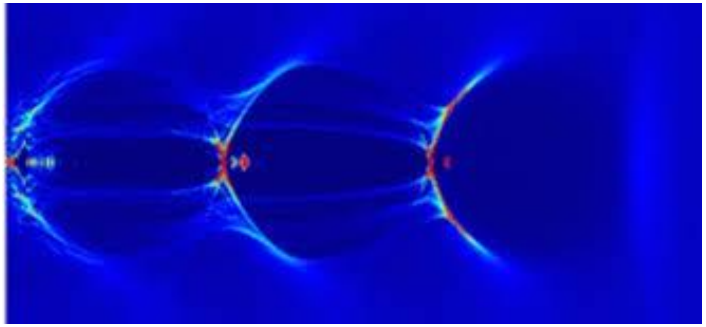
Advanced accelerators

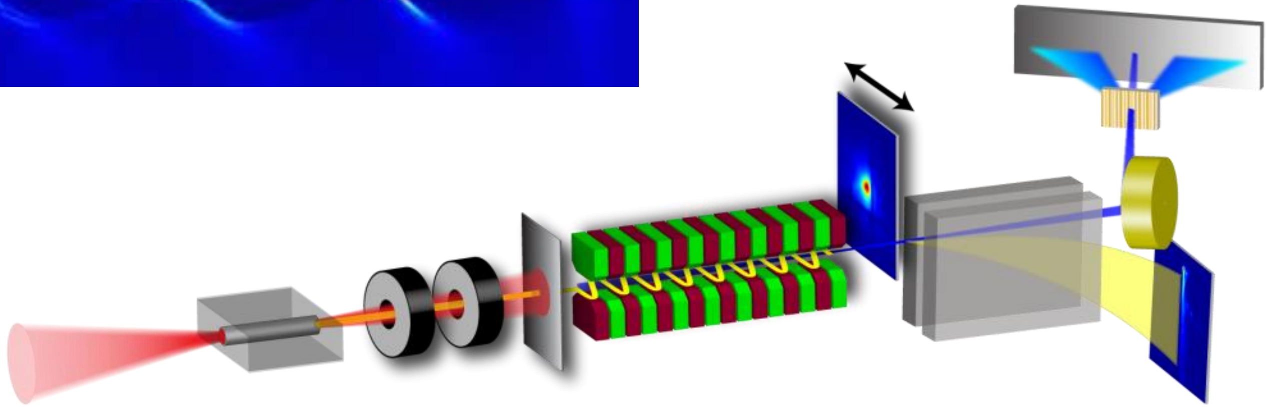
conventional accelerator
old-fashioned, clumsy

advanced accelerator
innovative, promising

Advanced accelerators

e.g. laser-plasma acceleration + undulator = short-pulse source or FEL



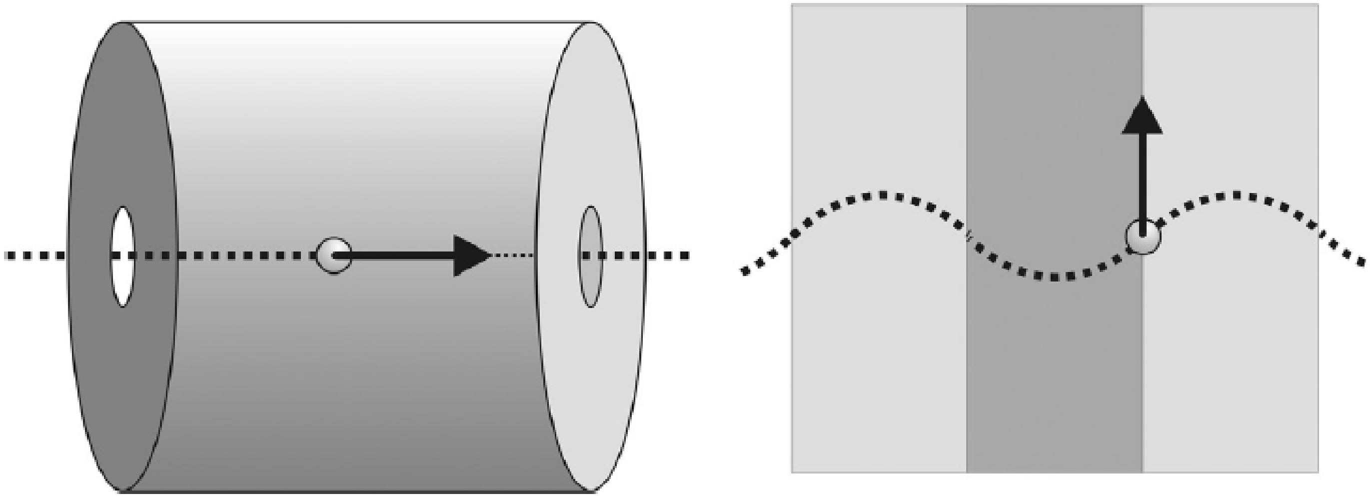


M. Fuchs et al., Nature Physics 5 (2009), 826

Laser-induced energy modulation

CHG in storage rings
HGHG and EEHG in linac-based FELs

$$E_{\text{eff}} = \vec{E} \cdot \vec{x} = \frac{K}{\gamma} \left| \vec{E} \right|$$

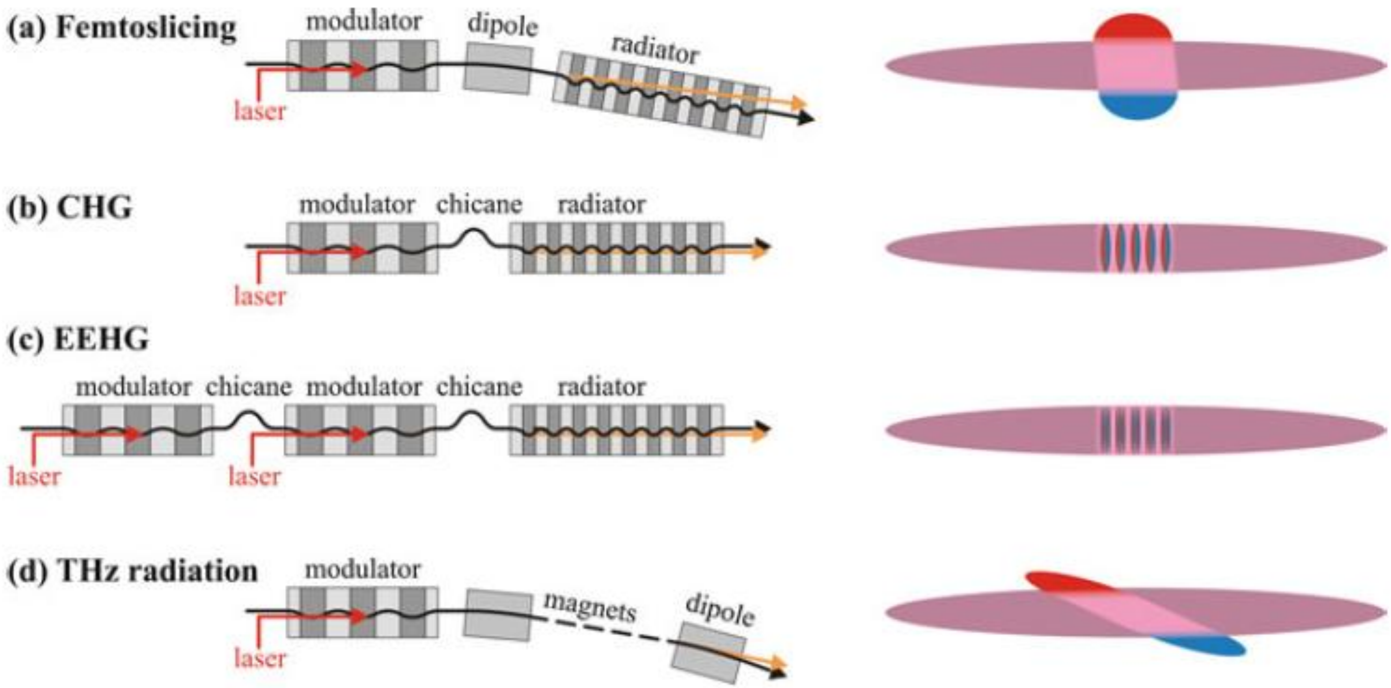


$$W = 100\,\text{mJ} \qquad A = 10^{-6}\ \text{m}^2$$

$$\Delta t = 50\,\text{fs} \qquad P = 2\,\text{TW} \qquad I = 2 \cdot 10^{18}\,\frac{\text{W}}{\text{m}^2} \qquad E = \sqrt{\frac{2I}{\varepsilon_0 c}} = 5.5 \cdot 10^{10}\,\frac{\text{V}}{\text{m}}$$

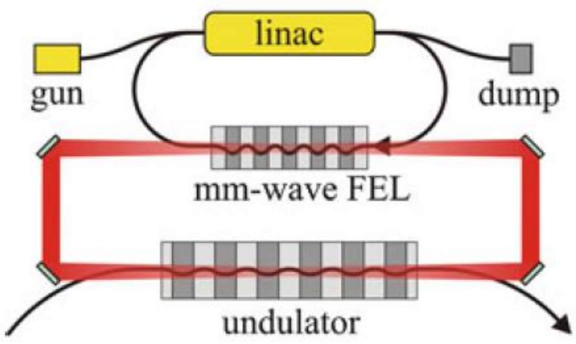
Laser-induced energy modulation

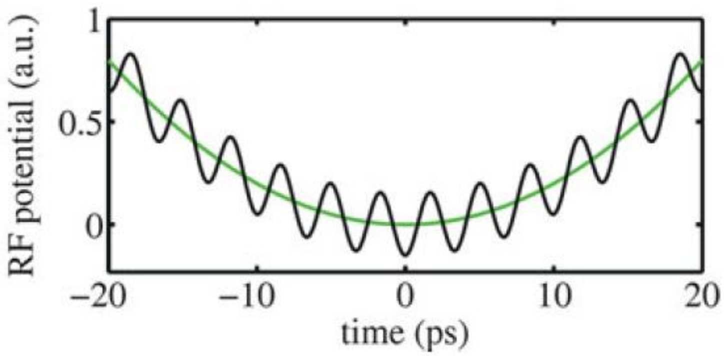
Applications in storage rings



Laser-induced energy modulation

Applications in storage rings



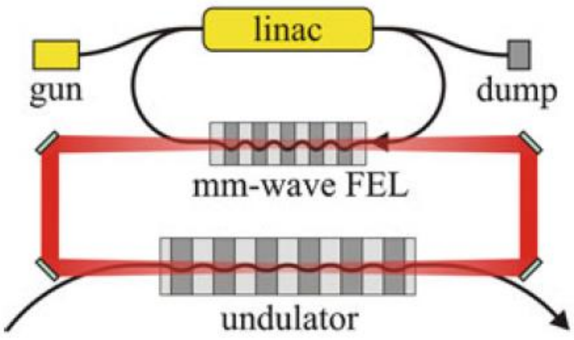


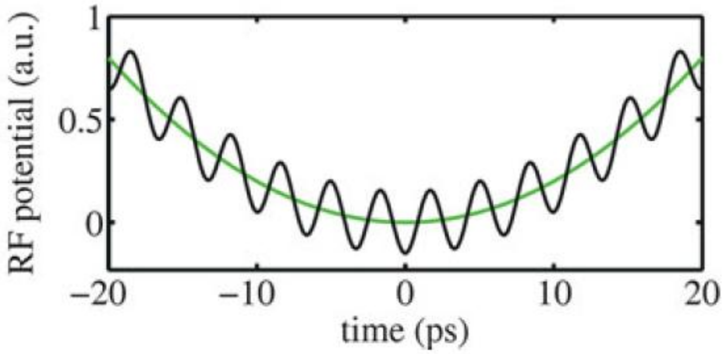
see Litvinenko et al., PAC 2001, Chicago, USA, p. 2614

far-IR FEL $\lambda \sim 1$ mm
CO2 laser $\lambda \sim 10$ µm (?)
Ti:sa laser $\lambda \sim 0.8$ µm (?)
requires correspondingly small α

Laser-induced energy modulation

Applications in storage rings





see Litvinenko et al., PAC 2001, Chicago, USA, p. 2614

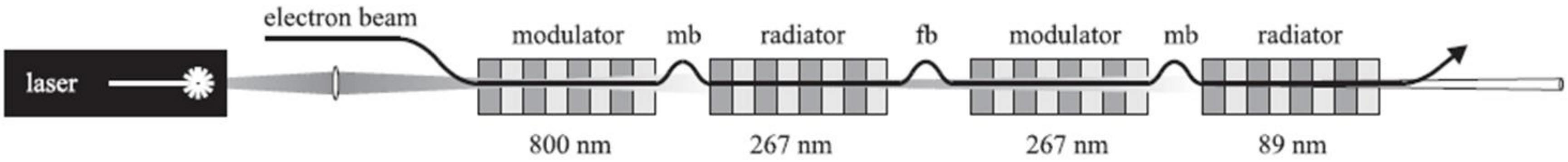
far-IR FEL $\lambda \sim 1$ mm
CO_2 laser $\lambda \sim 10$ μm (?)
Ti:sa laser $\lambda \sim 0.8$ μm (?)
requires correspondingly small α

but: R51 and R52, stochastic synchrotron radiation
limit ~ 300 fs (100 μm)

Y. Shoji, Phys. Rev. E54, R4556 (1996)
Y. Shoji, Phys. Rev. ST Accel. Beams 7, 090703 (2004)

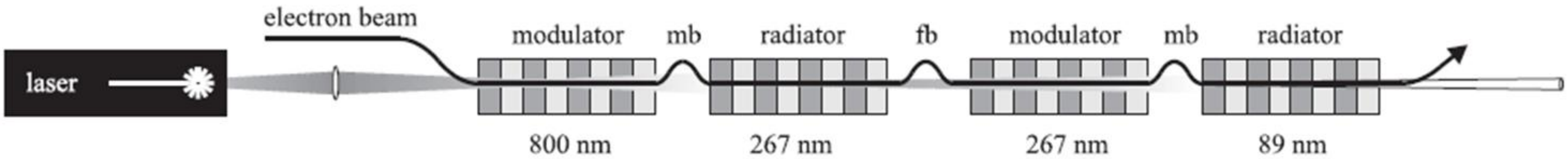
Laser-induced energy modulation

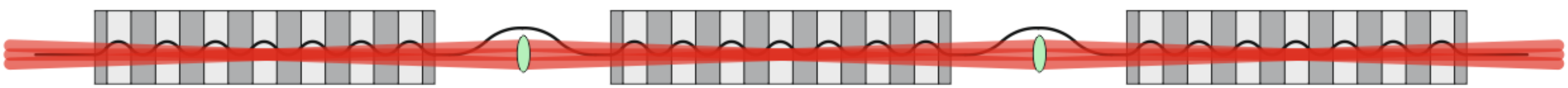
Applications in linacs ?



Laser-induced energy modulation

Applications in linacs ?





refokusing
of laser and
electrons

$W = 100\,\mathrm{mJ}$ $Q = 0.1\,\mathrm{nJ}$ $\Delta E = 1\,\mathrm{GeV}$