Laser undulators

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Laser undulators

FEL efficiency described by ρ

bunch current; undulator period; undulator parameter

$$\varrho = \frac{1}{4\gamma_r}\left[\frac{1}{\pi^2}\frac{I_b}{I_\alpha}\frac{\lambda_u^2}{\sigma_b^2}K^2\right]^{1/3}$$

resonant bunch energy; Alphen current, 17 kA; beam size

Laser E-field

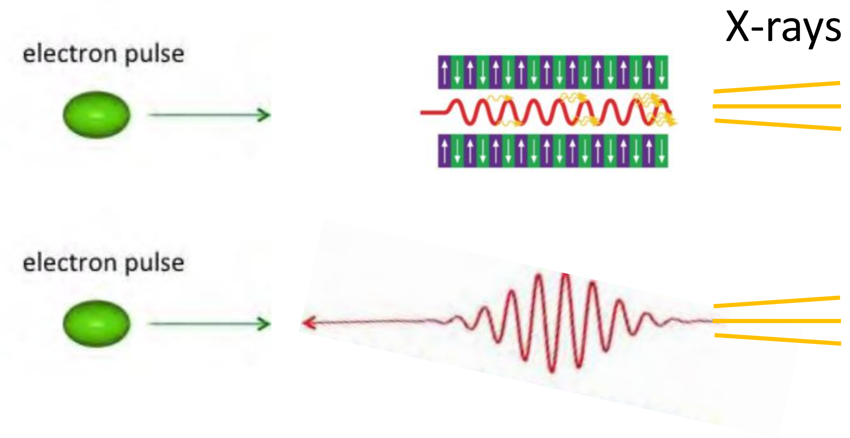
$$K = eE_u\lambda_u/(2\pi m_e c^2)$$

Standard undulator

λ_u=cm

Laser undulator

λ_u=μm



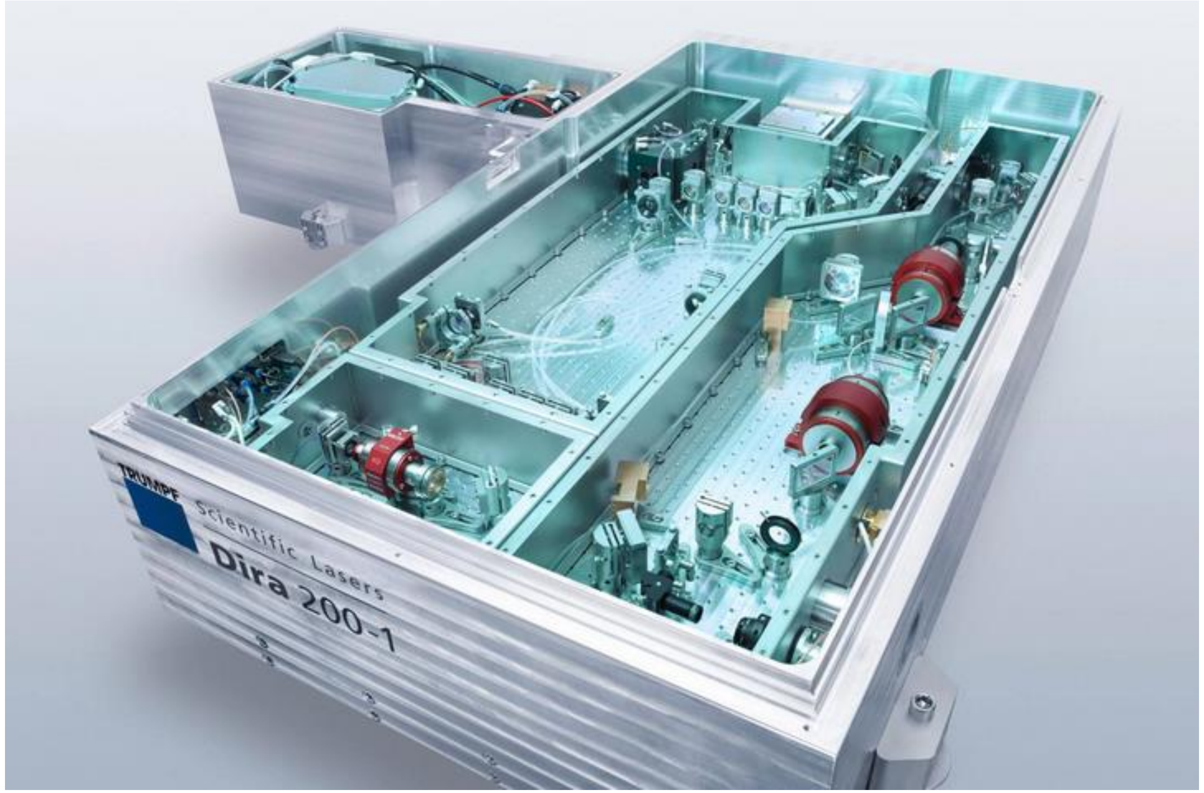
Desired laser properties for obtaining a high K value

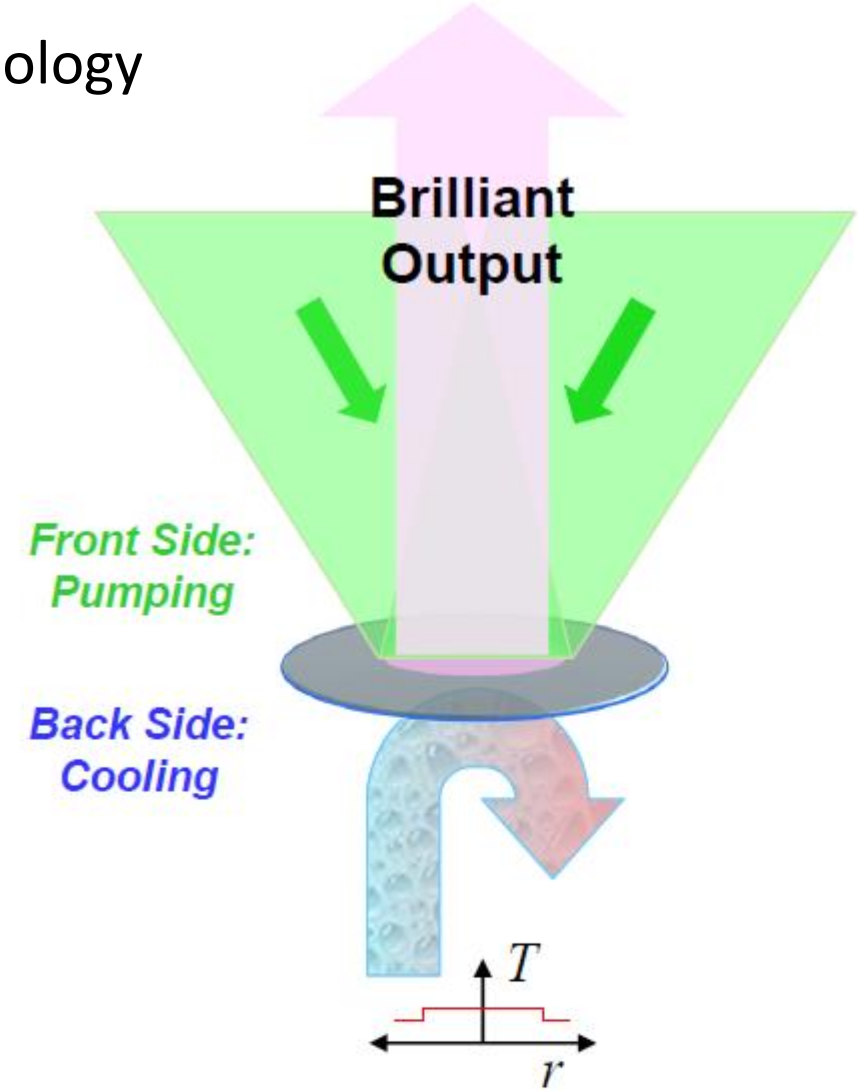
- high pulse energy (100 mJ)
- small waist (10 um)
- short pulse (1 ps)
- (long wavelength) – balanced against electron energy

We aim for ~100 kHz rep. rate → **high-power laser**

Powerful lasers

Thin-disk technology

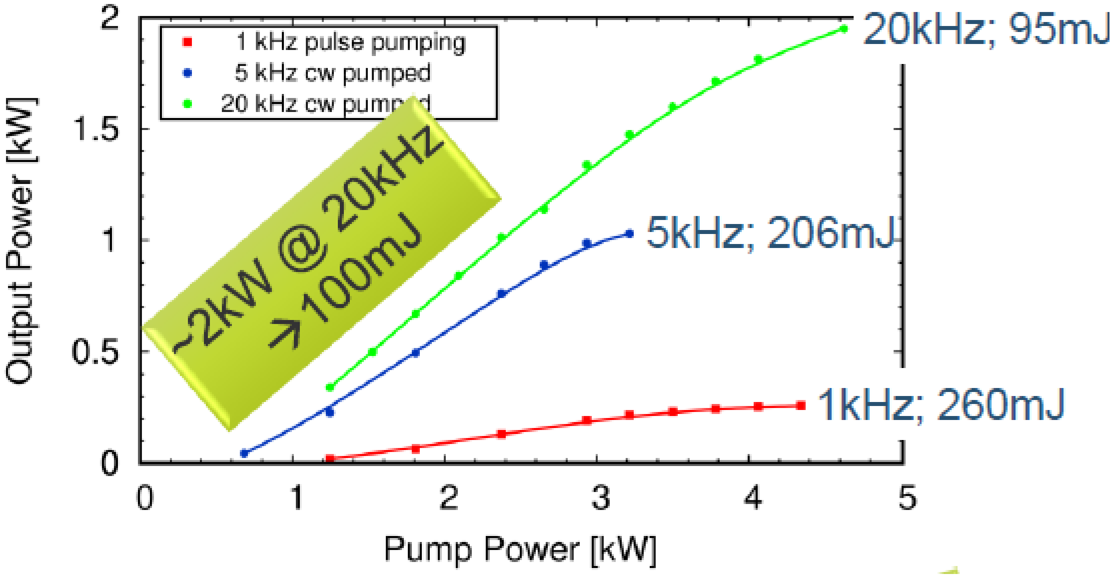


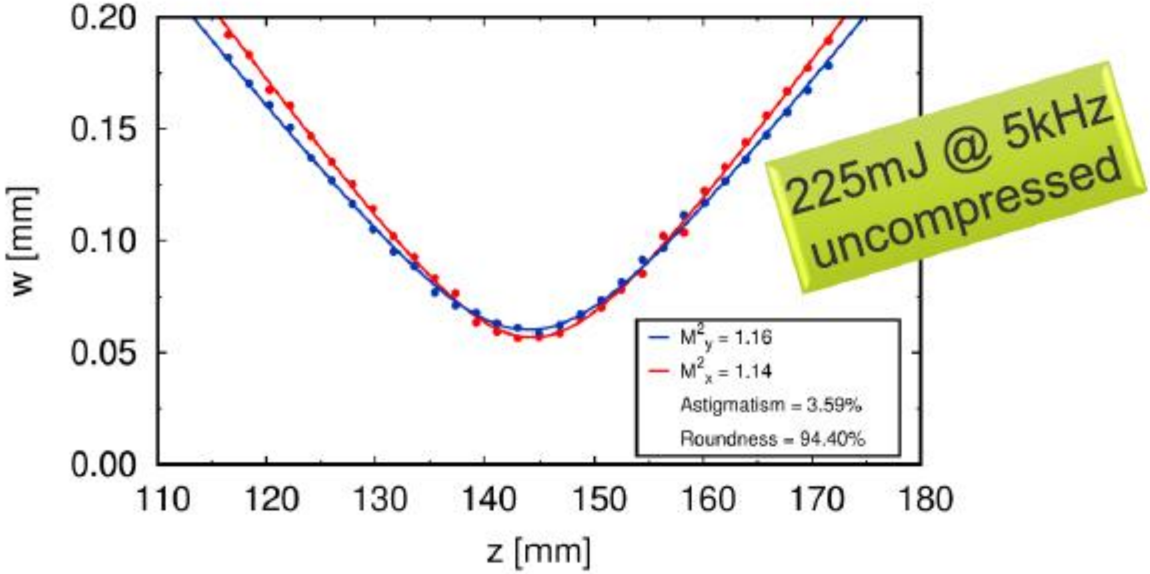


www.trumpf.com

Powerful lasers

Trumpf, Dira 1000-5: 1 kW, 200 mJ, 500 fs, λ=1 μm, M^2<1.4





- Dira Series: **200mJ; 1kHz; <1ps (standard)**

  Regen. amplifier **500W; 6-100kHz; <1ps (standard)**

  1-2kW; 5-100 kHz; <1ps (standard – new: 500fs // 400mJ)

Rapid development towards higher powers. We assume 50 mJ at 100 kHz in simulations.

Summary

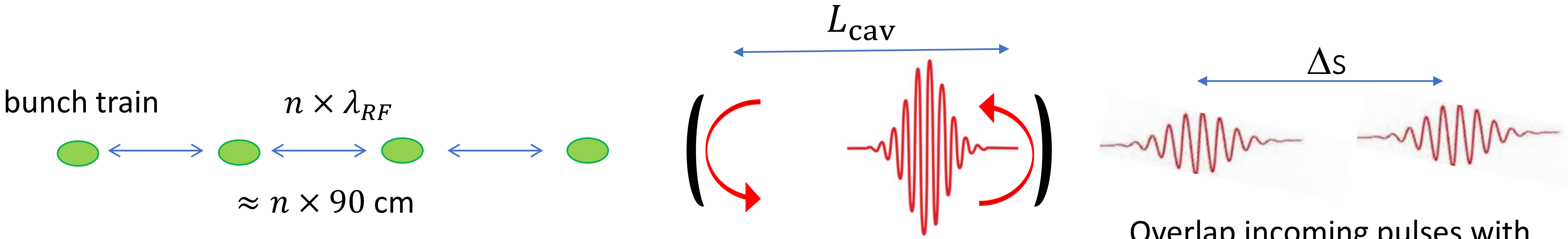
- High power laser necessary for efficient laser undulator

- Thin-disk laser technology offers promising output parameters for a laser undulator at 100 kHz rep. rate.

- We have also looked at enhancement cavities as a way to increase laser power. They can produce >100 kW average power but the ~100 MHz rep. rate associated with them is not compatible with our target rep. rate of 100 kHz.

Extra slides

High laser average power using enhancement cavity



$$2L_{\text{cav}} = \Delta s$$

Overlap incoming pulses with the pulse in the cavity -> build up of energy.

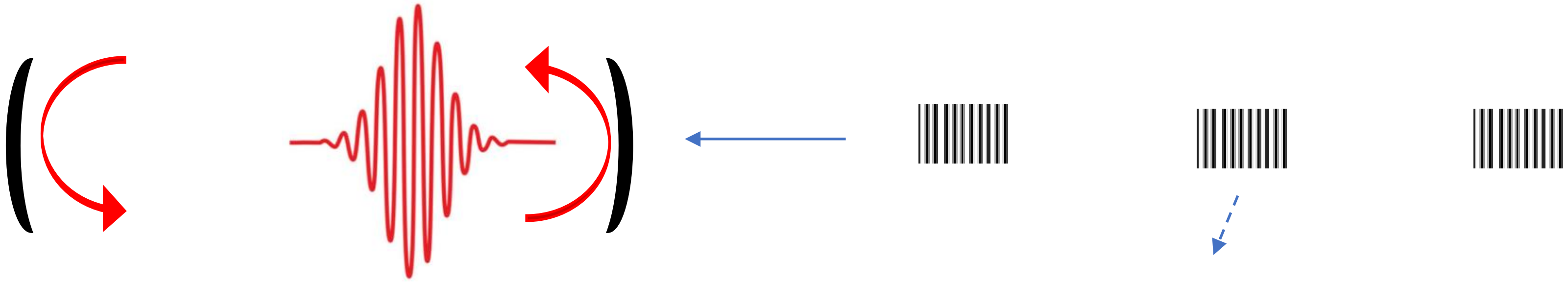
$$2L_{\text{cav}} = \lambda_{RF} = 90 \text{ cm} \text{ -> } 330 \text{ MHz rep. rate}$$

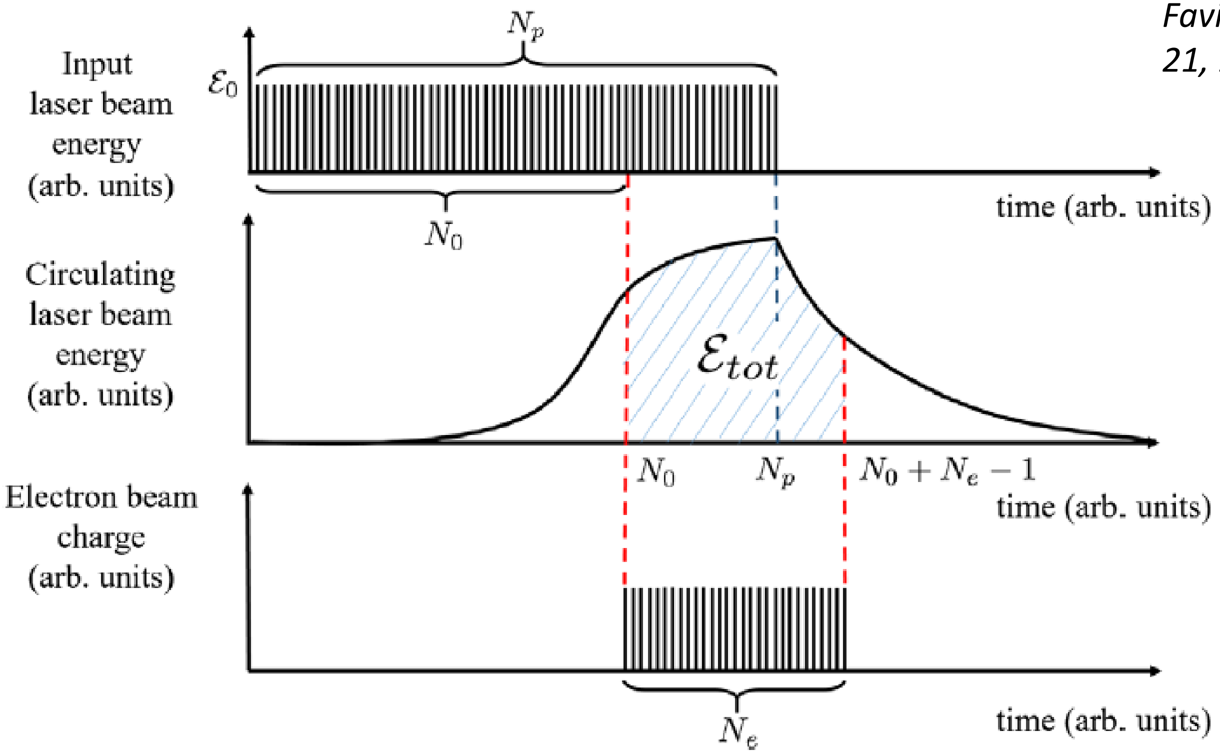
Laser input power ~100 W -> high intra-cavity average power ~600 kW

Carstens, Optics letters (2014)
Favier, Proc. of SPIE, 10387 (2017)

But MHz rep. rate, limited pulse energy (mJ) and quite large waist (>20 μm)
-> not perfect as a laser undulator but ok for ICS

High pulse energy using burst mode enhancement cavity





Favier, PRAB 21, 121601 (2018)

High pulse energy, >100 mJ

Relatively high average power, kW

Follow development of enhancement cavities, but **the high power thin-disk lasers are presently the best choice for laser undulators**, producing high pulse energies at 100 kHz