The low-α mode at the Metrology Light Source

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HZB Helmholtz Zentrum Berlin

PTB

associated workgroups:

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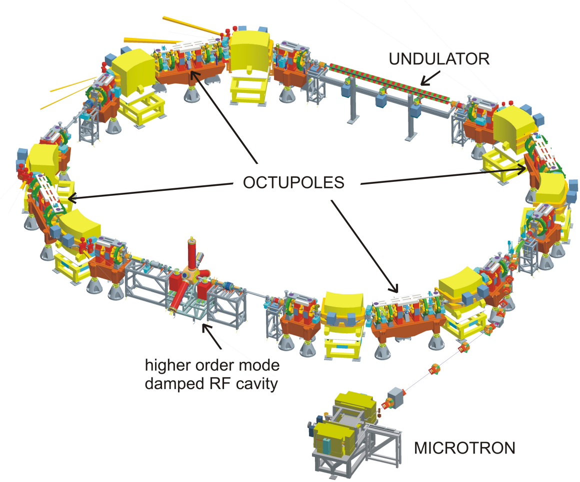
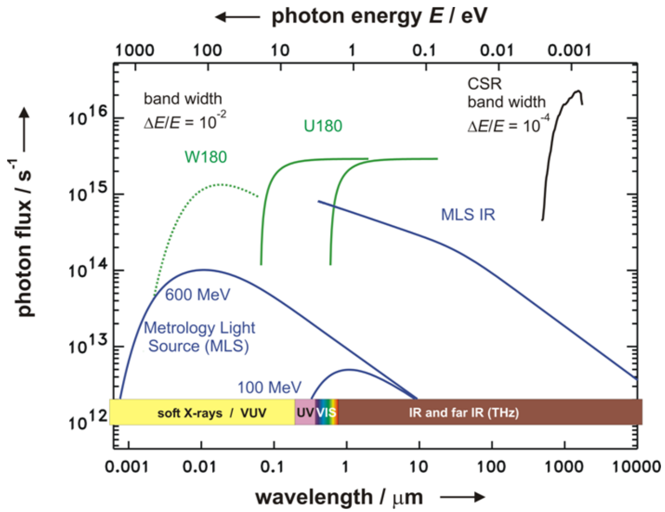
Outline

The MLS



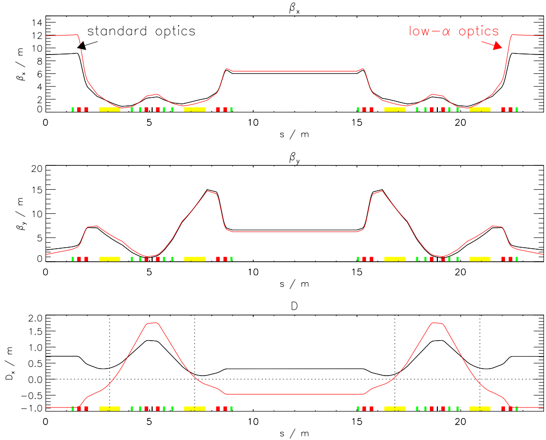
- $2\pi R = 48$ m
- $R_{\text{bend}} = 1.528$ m
- $E_e = 105 \ldots 629$ MeV
- E_{loss} / turn = $7 \ldots 9060$ eV
- $\frac{\Delta p}{p} = 0.7 \cdot 10^{-4} \ldots 4.2 \cdot 10^{-4}$
- $\tau_{\text{damp}} = 5$ s $\ldots 5$ ms
- $|\alpha| = 1 \cdot 10^{-5} \ldots 7 \cdot 10^{-2}$
- $f_{\text{RF}} = 500$ MHz
- $V_{\text{RF}} = 50 \ldots 500$ kV
- $h = 80 = 500$ MHz$/6.25$ MHz
- $I_e = 1$ pA $(1e^-) \ldots 200$ mA
- $Q_x \,/\, Q_y = 3.18 \,/\, 2.23$

MLS spectrum



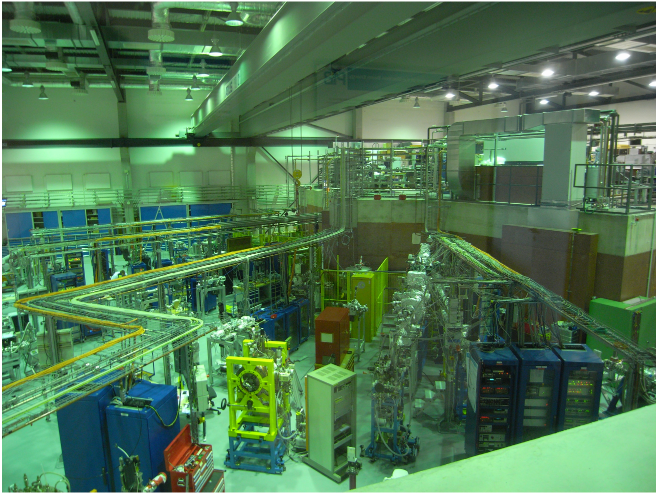
spectral range of the MLS

MLS optics



low-α optics induce D at cavity $\neq 0 \rightarrow$ quadrupole splitting

Beamlines



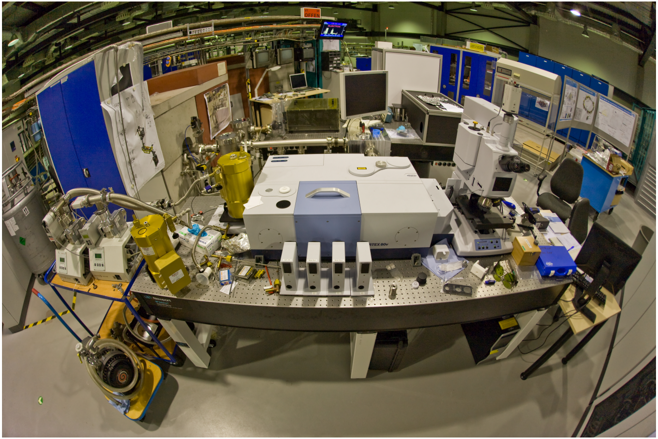
user beamlines

- IR*
- THz*
- DWL
- ID(*)
- EUV
- VUV

* beam ports at the roof

CSR beamports

- IR
- THz



43 mrad $\times$ 64 mrad, 32 mm clear aperture

CSR beamports

- IR
- THz

43 mrad $\times$ 64 mrad, 89 mm clear aperture

Spectrometer

vertex 80v (Bruker)

- up tp 0.1 cm^{-1}
- beamsplitters down to 2 cm^{-1}
- Martin-Puplett under construction

Detectors for CSR

room temperature

- DTGS
- Golay-cell
- Powermeter
- THz-camera
- Schottky diode[1]

cooled

- Si
- InSb
- Ge
- YBCO HEB [2]

[1] Deutsches Zentrum für Luft- und Raumfahrt, Germany
[2] Deutsches Zentrum für Luft- und Raumfahrt & Karlsruher Institut für Technologie, Germany

low-α operation

Low-α operation

- no injection in low-α optics
- synchronous ramping of involved magnets
- based on a sequence of optical states
- maximum current achieved in low-α optics: 180 mA
- low-α availability throughout the full energy range $E = 105\ \mathrm{MeV} \ldots 629\ \mathrm{MeV}$
- goal: energy ramping at arbitrary α

Bunch lengths

energy / MeV	standard optics σ / ps	low-α optics σ / ps
629	22	1.3
450	17	0.7
250	9	0.4
105	4	0.7

calculated zero current rms bunch lengths for achieved machine settings

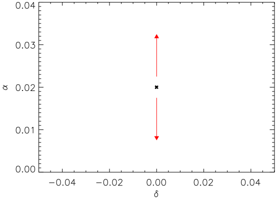
Tuning higher orders of α

$$\underset{magnet:}{\alpha(\Delta p/p)} = \underbrace{\alpha_0}_{quadrupole} + \underbrace{\alpha_1}_{sextupole} \frac{\Delta p}{p} + \underbrace{\alpha_2}_{octupole} \left(\frac{\Delta p}{p}\right)^2 \ldots$$

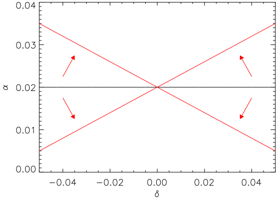
Tuning higher orders of α

$$\alpha(\Delta p/p) = \underbrace{\alpha_0}_{quadrupole} + \underbrace{\alpha_1}_{sextupole} \frac{\Delta p}{p} + \underbrace{\alpha_2}_{octupole} \left(\frac{\Delta p}{p}\right)^2 \ldots$$

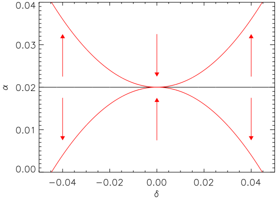
magnet:



quadrupole $\longrightarrow \alpha_0$

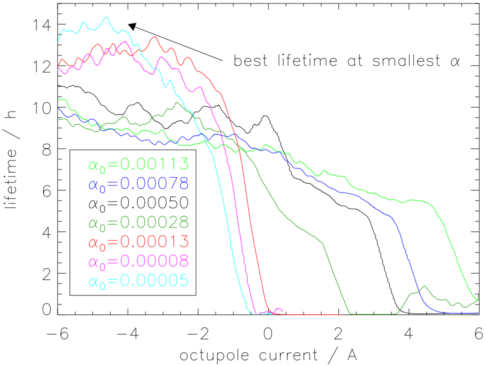


sextupole $\longrightarrow \alpha_1$



octupole $\longrightarrow \alpha_2$

Octupole relevance

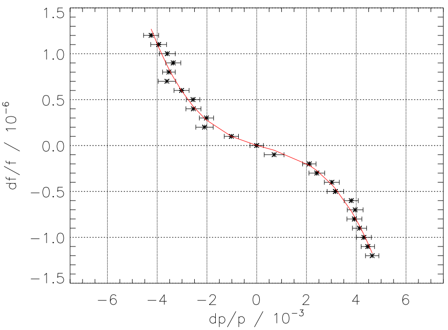


octupole current shifts lifetime cutoff in respect to α

$\alpha\left(\frac{\Delta p}{p}\right)$

$$\frac{\Delta L}{L} = \alpha \frac{\Delta p}{p} = -\frac{\Delta f}{f}$$

$$629\ \mathrm{MeV}, 6.7\ \mathrm{kHz}, 450\ \mathrm{kV}, I_{\mathrm{oct}} = -6\ \mathrm{A}$$



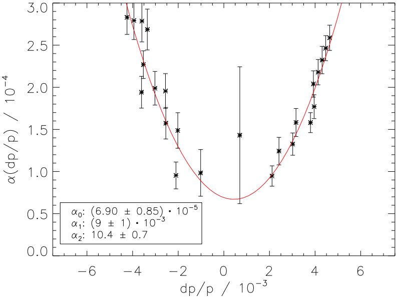
direct measurement of $\alpha\left(\frac{\Delta p}{p}\right)$ via Compton backscattering

$\alpha\left(\frac{\Delta p}{p}\right)$

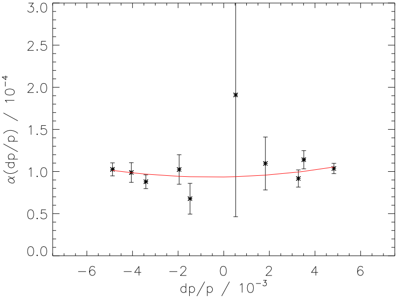
$$\alpha(\frac{\Delta p}{p}) = -\frac{\Delta f}{f} \Big/ \frac{\Delta p}{p}$$

$$629\ \mathrm{MeV}, 6.7\ \mathrm{kHz}, 450\ \mathrm{kV}$$

octupole $= -6$ A

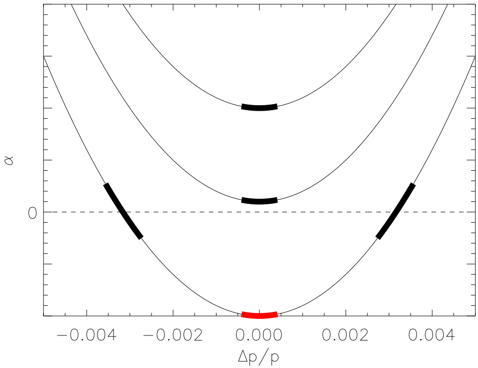


octupole $= -1$ A



direct measurement of $\alpha\left(\frac{\Delta p}{p}\right)$ via Compton backscattering

Double beam

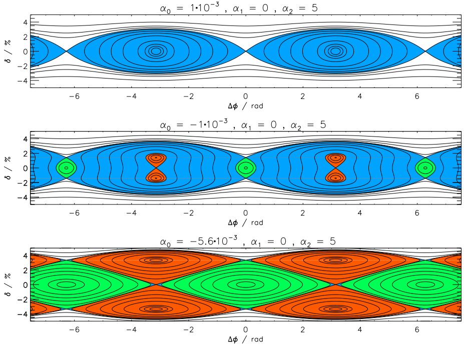


$$\Delta\dot{\psi} = \frac{2\pi q\alpha}{T_0\beta^2}\frac{\Delta E}{E} \qquad \Delta\dot{E} = \frac{eU_0\cos(\psi_0)}{T_0}\Delta\psi$$

$$\Delta\dot{\psi} = 0 \propto \alpha\frac{\Delta E}{E} \quad \rightarrow \quad \left.\begin{array}{l} \frac{\Delta E}{E} \propto \frac{\Delta p}{p} \\ \alpha = \alpha_0 + \alpha_2\left(\frac{\Delta p}{p}\right)^2 \end{array}\right\} \text{3 solutions}$$

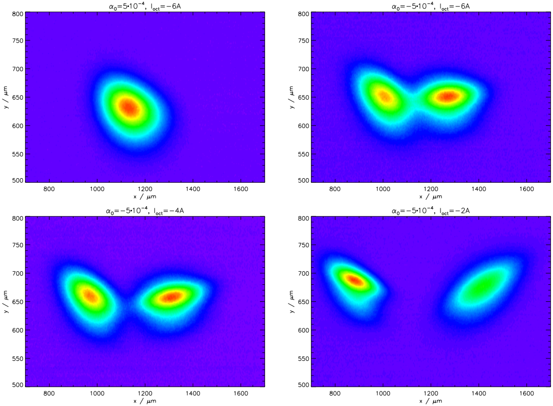
Double beam

$$\mathscr{H} = \pi f_{\mathrm{rf}} \left(\alpha_0 \delta^2 + \alpha_2 \frac{\delta^4}{2} \right) + \frac{f_{\mathrm{rev}} e U_0}{E} \cos\left(\Delta\Phi\right)$$



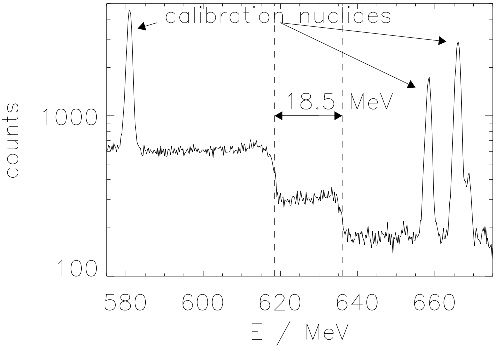
crossing of $\alpha = 0$ without phase-jumping

Double beam



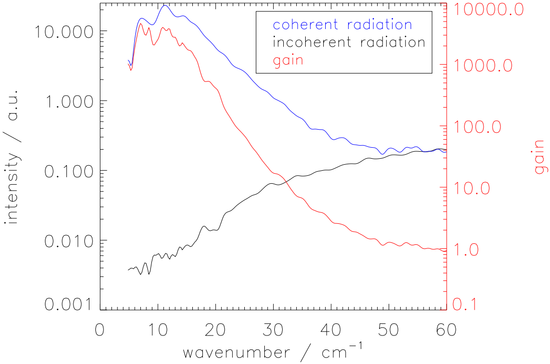
transverse source point in dispersive section

Compton backscattering



Compton backscattering measurement of a double beam CO_2-Laser ($10\mu\mathrm{m}$)

CSR spectral range



example CSR spectrum in standard low-α optics
up to 60 mW

Summary

- The MLS is optimized for the generation of coherent synchrotron radiation. Octupole magnets offer a highly flexible and stable low-α operation.

- Outlook
  - detailed single bunch measurements
  - 11/2010 multi bunch feedback system
  - 2011 splitting of the quadrupole families


PTB
thank you
MLS building

for further reading

- R. Müller et al., *IR and THz beamlines at the Metrology Light Source of the PTB*, Proc. of WIRMS2009 in AIP Conference proceedings 1214, 32-35 (2010)
- R. Klein et al.,*Absolute Measurement of the MLS Storage Ring Parameters*, PRST-AB 11, 110701(1-10) (2008)
- R. Müller et al.,*CSR at the MLS*, Proceedings of EPAC08, 2058-2060 (2008)
- R. Müller et al.,*Planned IR-beamlines at the Metrology Light Source of PTB*, Infrared Physics & Technology 49, 161-166 (2006)
- G. Wüestefeld et al., *Coherent THz measuremets at the Metrology Light Source*, Proceedings of IPAC10, 2508-2510

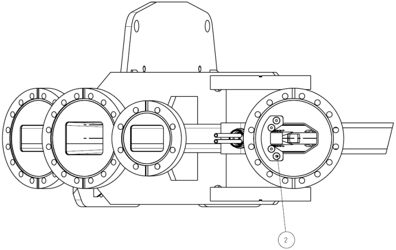
The MLS

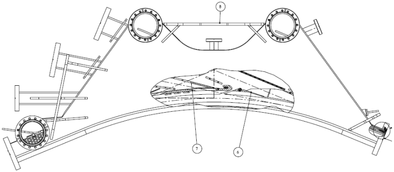
location of the MLS next to BESSY II

Dipole vacuum chamber

$$h = 42 \text{ mm}$$

$$d = 70 \text{ mm}$$



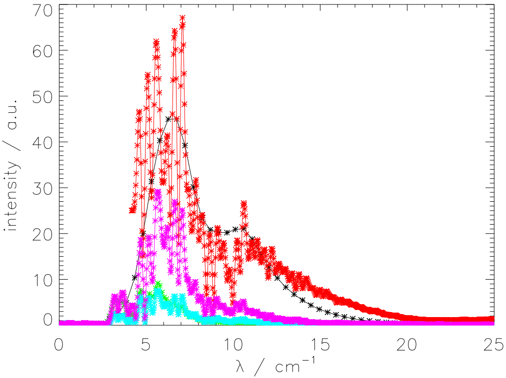


Whispering gallery modes at the MLS?

shielding cutoff: $\lambda_0 \approx 2h\left(\frac{h}{R}\right)^{\frac{1}{2}} = 0.014\ \mathrm{m} \rightarrow 0.7\ \mathrm{cm}^{-1}$

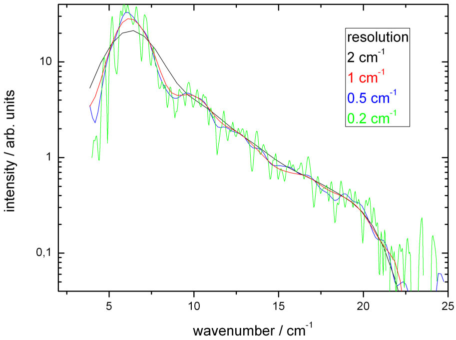
z-cut-quartz window: $d = 6\ \mathrm{mm} \rightarrow \Delta = 0.6\ \mathrm{cm}^{-1}$
mylar beamsplitter: $d = 125\ \mu\mathrm{m} \rightarrow \Delta = 26\ \mathrm{cm}^{-1}$
mylar beamsplitter: $d = 50\ \mu\mathrm{m} \rightarrow \Delta = 66\ \mathrm{cm}^{-1}$

CSR high resolution



high resolution CSR spectrum THz beamline

CSR high resolution



high resolution CSR spectrum IR beamline
wedged window