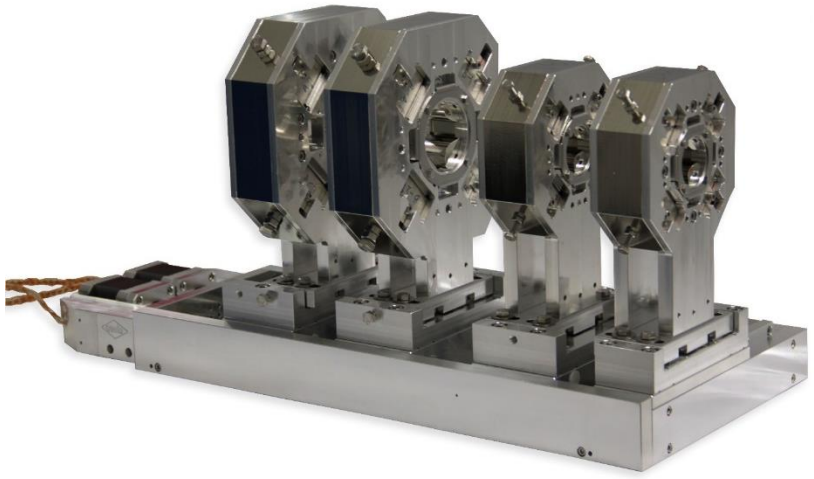
Developing the current experimental research into laser acceleration to a pre-commercial level

Laser Applications at Accelerators Conference 2015

Jakob Matthias Krämer

Outline

- Motivation
- Emittance increase in a focusing system for large energy spread beams
- Design and test results of an electron beam focusing system dedicated for these challenges



Motivation

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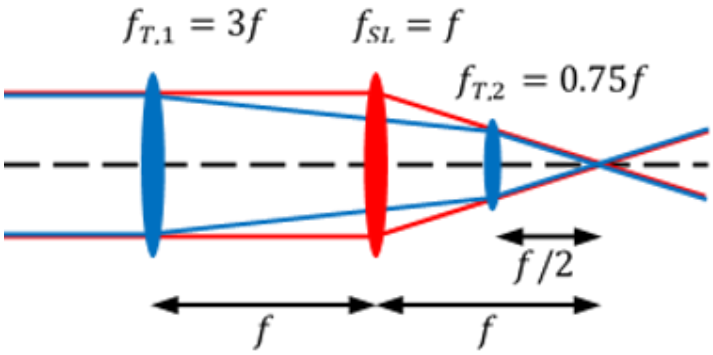
- Beam properties of laser accelerated beam:
  - Large divergence and large energy spread
- Beam transport difficult due to
  - Chromatic aberrations of quadrupoles
  - Emittance increase
- Similar situation at Helmholtz-Centre Dresden Rossendorf:
  - conventional accelerators, but beam chirped in Linac for some settings ($\delta E_{rms} < 2\%$)
  - Strong focusing for Thomson scattering (<20 mrad)

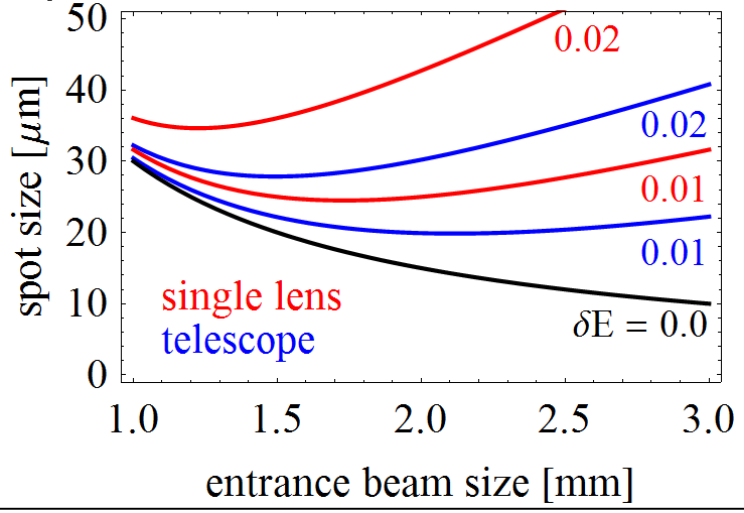
Chromatic aberrations

- Higher particle energies – longer focal length
- Proposed improvement: telescope (blue) instead of single lens (red)
  - For compact design without dipoles / sextupoles
- Simple model for explanation:

  $M_F = \begin{pmatrix} 1 & 0 \\ -\frac{1+\delta E}{f} & 1 \end{pmatrix}$, $M_D = \begin{pmatrix} 1 & l \\ 0 & 1 \end{pmatrix}$, transp. matrices for lens and drift

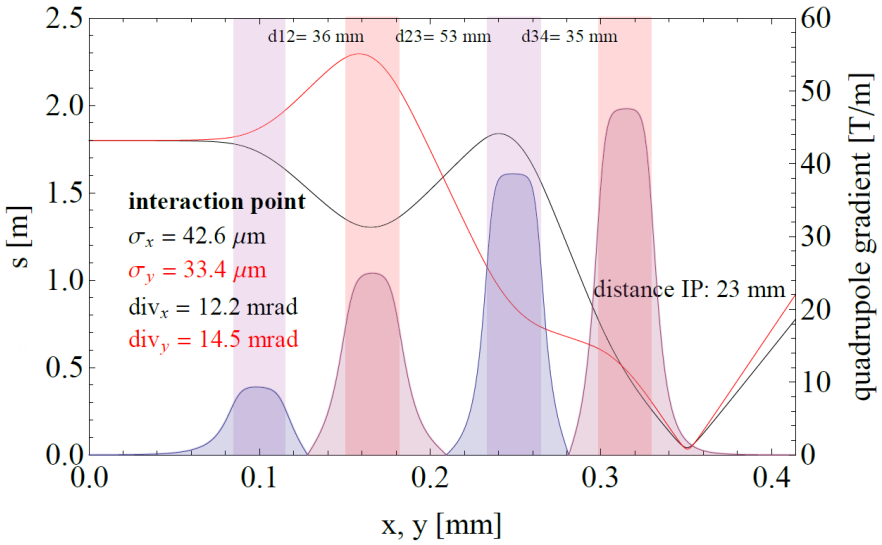
- Beam transport $B_1 = M \cdot B_0 \cdot M^T$, with beam matrix $B = \begin{pmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{pmatrix}$ directly shows the improvements by using a telescope





Full beam transport

- Parameters for Thomson application at HZDR
  - Electron energy: 20 – 30 MeV
  - energy spread rms: <0.02
  - Divergence on target: <20 mrad
  - Emittance: 10 – 20 mm mrad



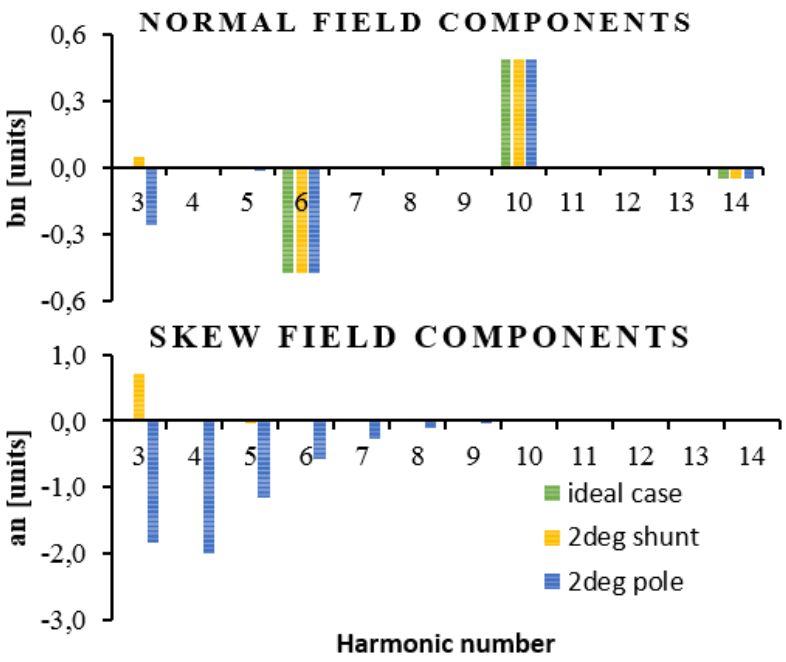
Motors by OWIS

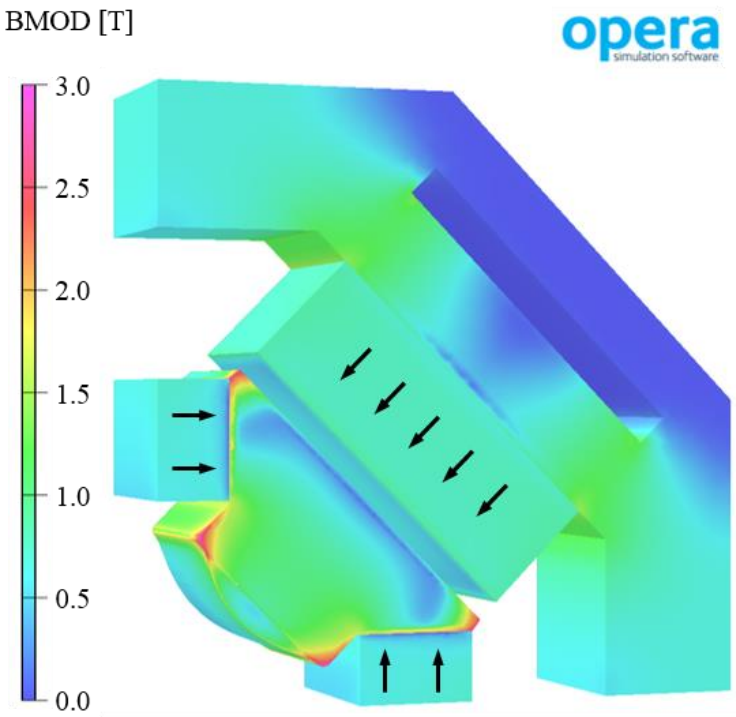
Used codes: TRANSPORT and ELEGANT

TRANSPORT Simulation Code, SLAC-R-530
M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation,"
Advanced Photon Source LS-287, September 2000

Magnet design

- Design made with Opera 2D & 3D
- Permanent magnet material: Sm_2Co_{17}
- Field errors due to magnet errors
- Shunt for shimming





Cobham Antenna Systems,
Vector Fields Simulation Software,
Kidlington, UK

Harmonic content from 2D simulation

Magnet test results

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- Hall mapper and slow rotating coil measurements

	Q1	**Q2**	**Q3**	**Q4**
Integ. Gradient [Tm/m]	0.486	-1.148	1.598	-1.980
Magn. Length [mm]	45.33	44.45	39.45	39.18
Gradient [T/m]	10.72	-25.83	40.51	-50.54
Aperture diameter [mm]	30	30	20	20
Good field radius [mm]	9	9	6	6
Integ. field error ± [%]	0.06	0.06	0.10	0.10
Amplitude dB/B0 , n3-10 [%]	0.08	0.10	0.13	0.15
Center offset, Dx [mm]	0.01	0.02	0.00	-0.03
Center offset, Dy [mm]	0.00	-0.03	0.02	0.03
Magnet rotation [mrad]	0.06	0.70	0.06	0.35

Magnet test results

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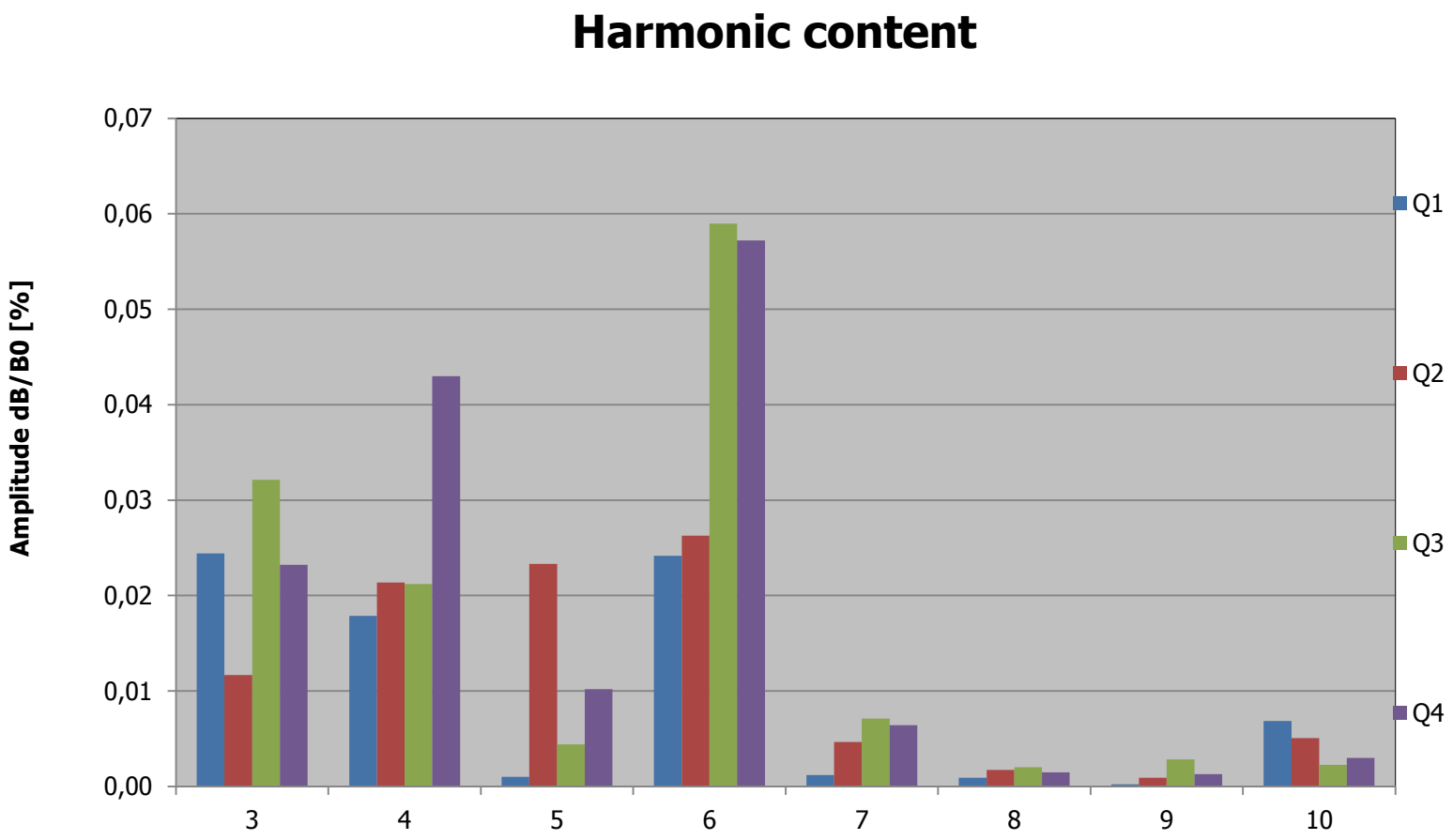

Commissioning in Dresden and emittance scan

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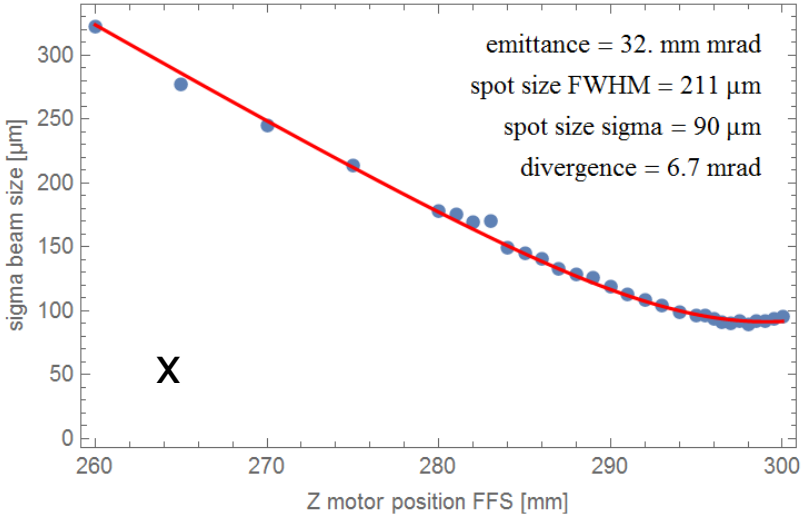
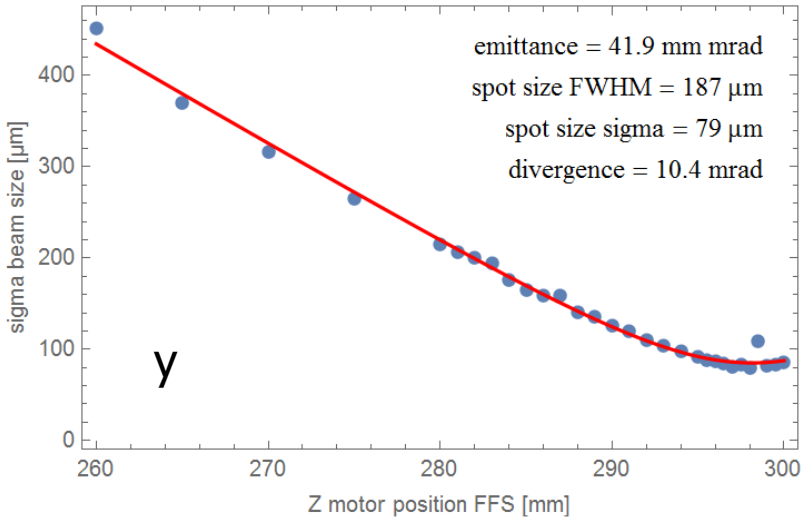
- Moving whole FFS in beam direction away from target will probe the waist of the beam (parallel beam input)
- Lanex screen to determine beam size
- Later: wire scanner
- Machine setting was not good in the test run (large emittance)





LANET

Summary

- Chromatic aberrations are one of the main challenges when transporting laser accelerated beams
- A telescope focusing system of permanent quadruple magnets was developed for these applications

jmkr@danfysik.dk

Thank you for your attention!

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