Elettra Sincrotrone Trieste

Screens for transverse profile measurements at FERMI

M.Veronese

on behalf of the FERMI diagnostics team

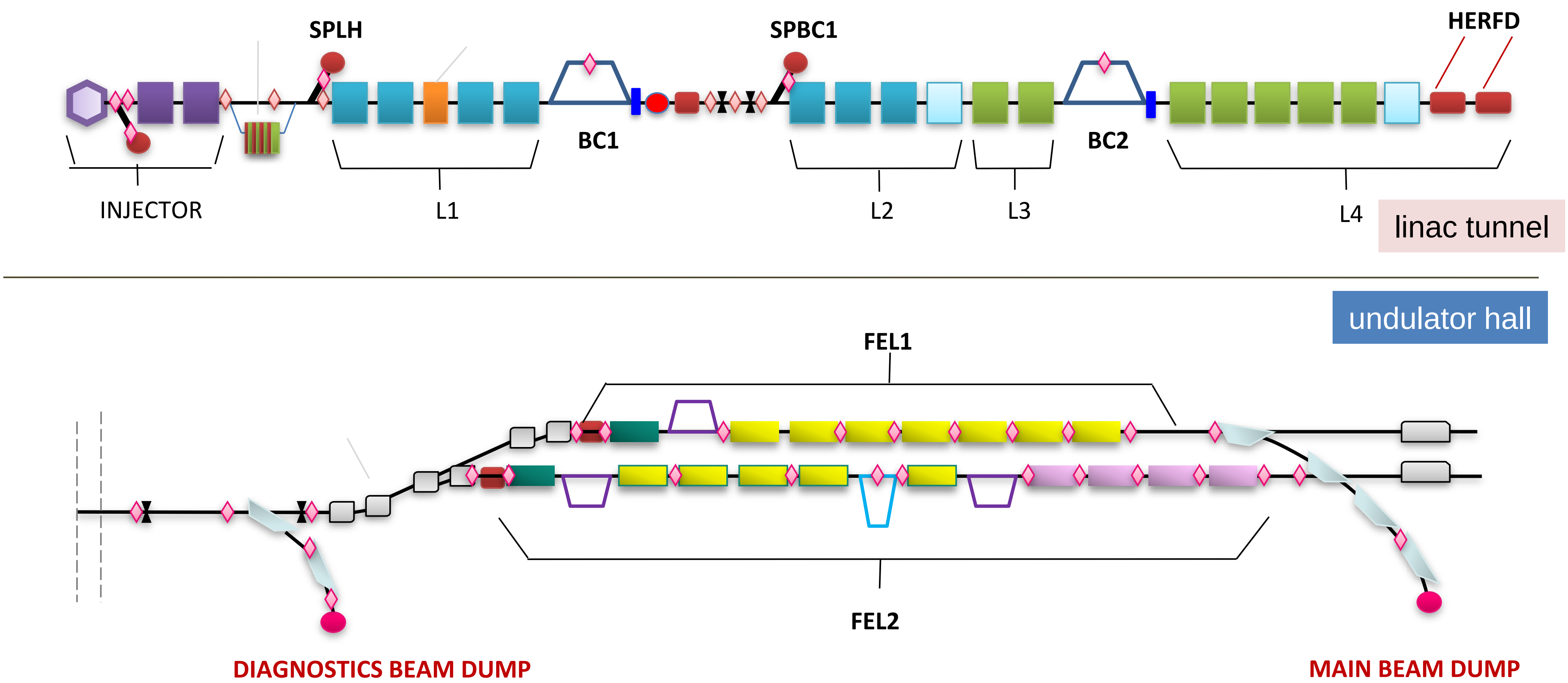
OUTLINE

- ✓ FERMI FEL
- ✓ STANDARD SCREENS
- ✓ SPECTROMETER SCREENS
- ✓ INTRA UNDULATOR SCREENS
- ✓ FEL SCREEN
- ✓ SEED LASER ALIGNMENT
- ✓ UV SCREEN
- ✓ FEEDBACK SCREENS
- ✓ CONCLUSIONS

FERMI FEL

- ✓ FERMI is a Seeded FEL User facility
- ✓ Location: Trieste (Italy)
- ✓ Wavelength range 100-4 nm (FEL1 + FEL2 lines)
- ✓ UCLA style GUN, 700pC, 1 mm- mrad norm. emittance
- ✓ Normal conducting Linac, 50Hz, 1.5 GeV
- ✓ 2 Bunch Compressors
- ✓ FEL1 line: single stage HGHG
- ✓ FEL2 line: double stage HGHG + fresh bunch

FERMI LAYOUT



~40 screens from the gun to the main beam dump

ORIGINAL FERMI CDR TYPES

- ✓ 3 injector (OTR + YAG:Ce)
- ✓ 17 standard screens (OTR + YAG:Ce)
- ✓ 2 Laser heater screens (OTR+ YAG:Ce + Chromox)
- ✓ 2 intra bunch compressor screens (OTR + YAG:Ce)
- ✓ 5 spectrometer screens (OTR + YAG:Ce)
- ✓ 15 intra undulator screens

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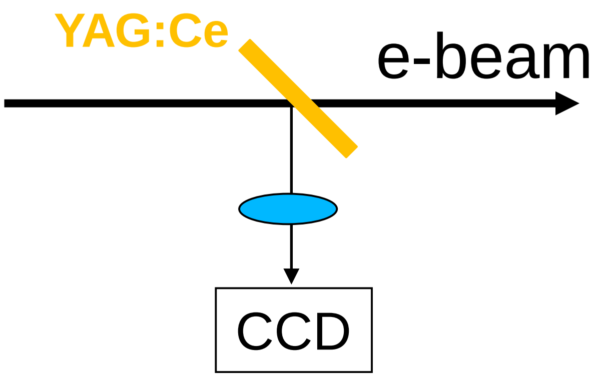
STANDARD SCREENS



Geometry:

45 deg YAG:Ce wrt to e-beam

90 deg optics wrt to e-beam

Emitter:

Lebow OTR → 1 micron Al foil

Crytur YAG:Ce → single crystal, thickness 0.1mm, doping 0.18%

Imaging system:

SIGMA 105 macro lens, Basler CCD camera ScA780-58gm, GigE

Horizontal FOV 17mm, M=0.4

Pros:

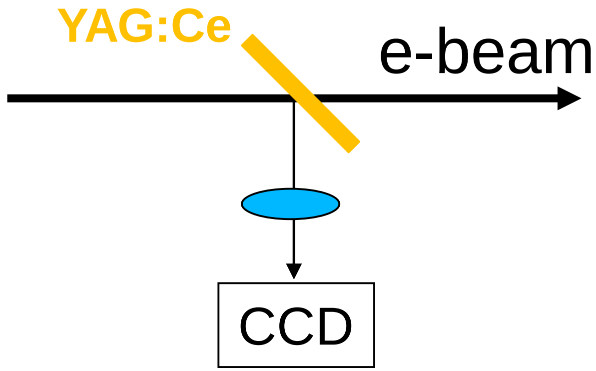
fast pneumatic actuators, small longitudinal occupation, large FOV

Cons:

Magnification not constant in horizontal plane

Limited resolution for emittance measurement

Spectrometer SCREENS



Geometry:

45 deg YAG:Ce orientation wrt to e-beam

90 deg optics orientation wrt to e-beam

Emitter:

Lebow OTR → 3 micron Al foil

Crytur YAG:Ce →single crystal , thickness 0.1mm, doping 0.18%

Imaging system:

SIGMA 105 lens + Basler CCD camera ScA1400-17gm, GigE

Horizontal FOV 45mm, M=0,2

Neutral density variable attenuator

Pros:

fast pneumatic actuators, small longitudinal occupation

Cons:

Magnification not constant in horizontal plane. Limited depth of field

Limited resolution high energy zones, 50Hz only on ROI

INTRAUNDULATOR SCREENS

Geometry:

quasi-normal YAG wrt e-beam

90 deg optics wrt e-beam

Emitter:

Baikowskii Optical ceramic, YAG:Ce → doping 0,5%, thickness 0.1mm

Imaging system:

SIGMA 150 APO macro lens + Basler CCD camera ScA1300-32gm, GigE

Horizontal FOV 6 mm, M=0,7. Neutral density variable attenuator

Pros:

COTR immune geometry, high resolution <15 micron, no issues with depth of field. Mechanical design allows more complex setups

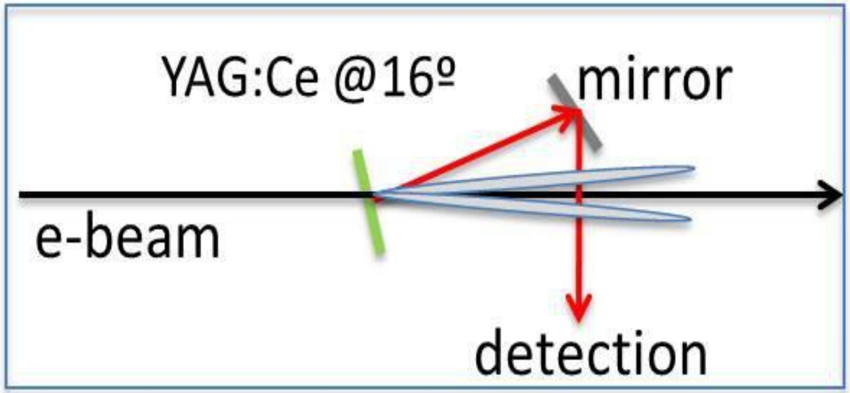
FEL radiation profile measurement possible

Cons:

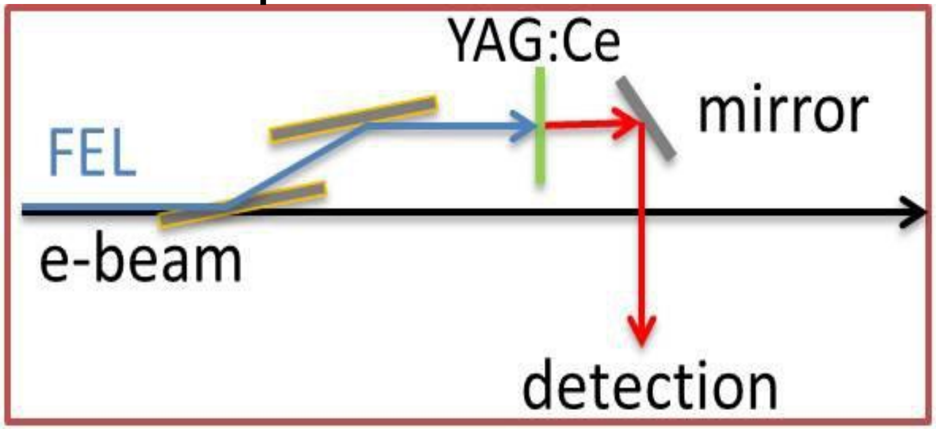
50Hz operation only on ROI.

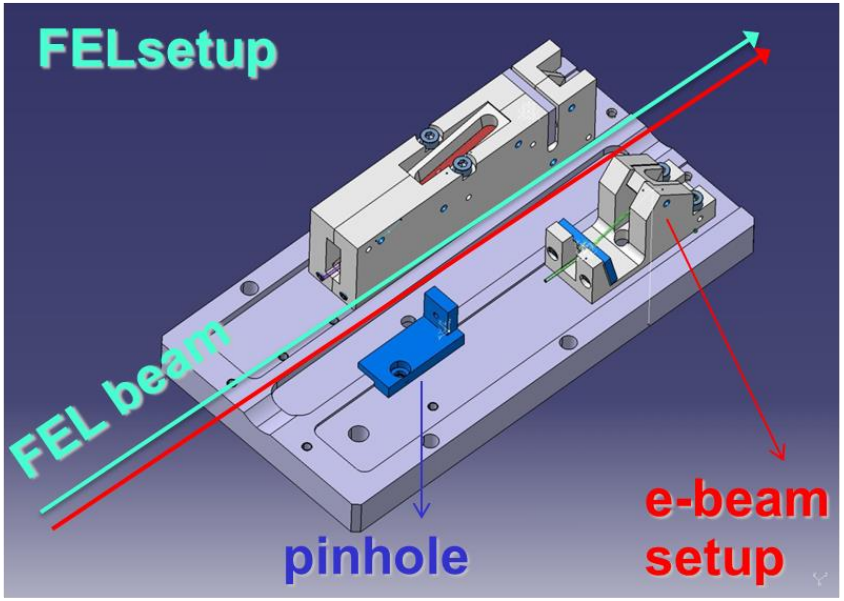
INTRA UNDULATOR SCREENS

e-beam setup



FEL setup

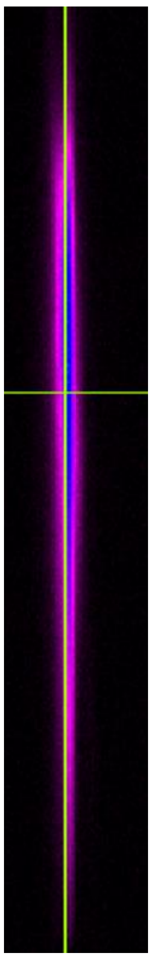


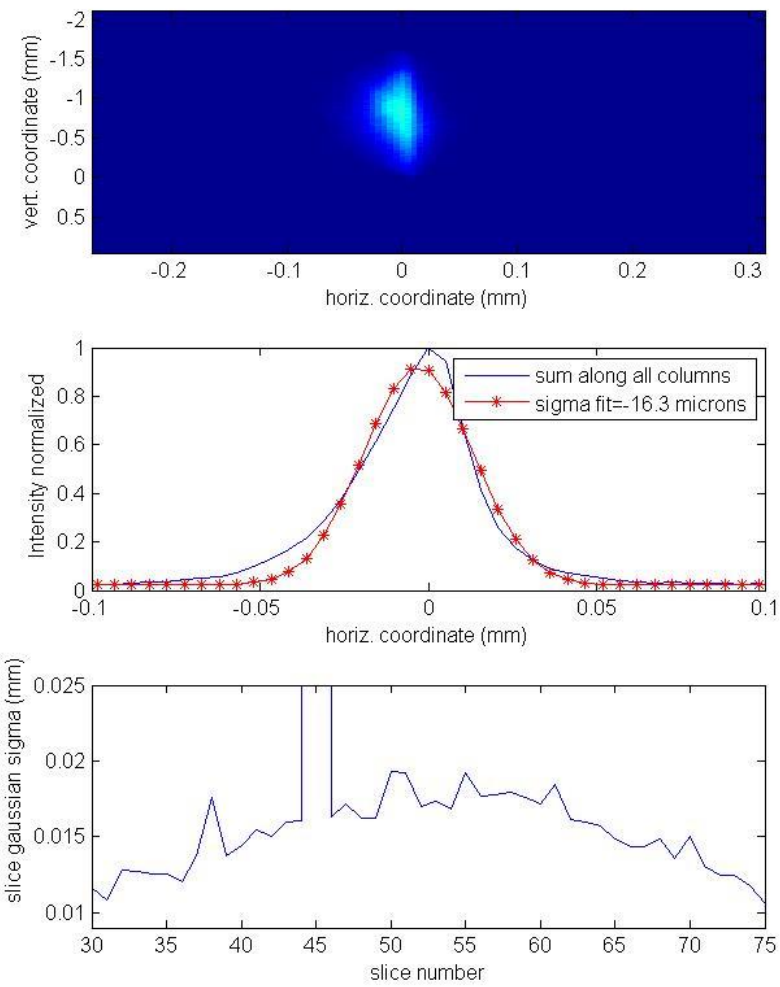


M.Veronese et al., IBIC12, TUPB76

INTRA UNDULATOR SCREENS

Application: imaging of e-beam profile





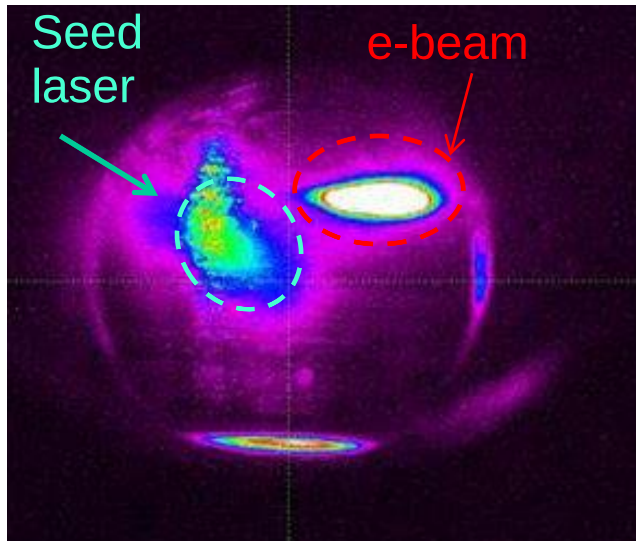
Raw image

Horizontal projection

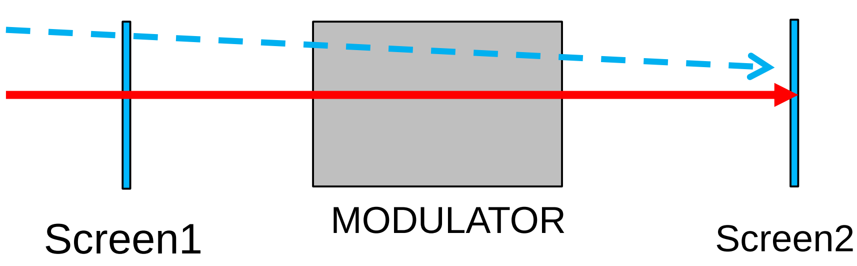
slice= sum of 6 rows
in Gaussian sigma ~ 12μm

INTRA UNDULATOR SCREENS

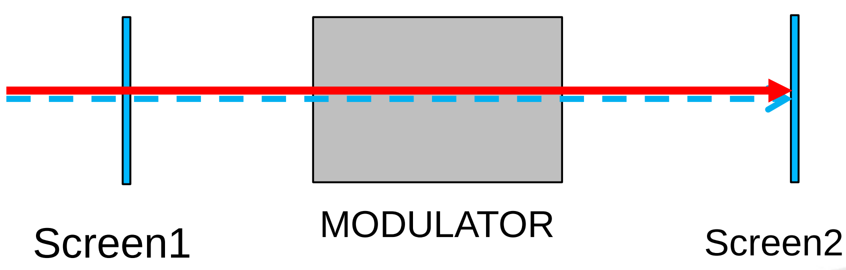
Application: overlap of seed laser and e-beam trajectory



Seed laser
λ=260nm



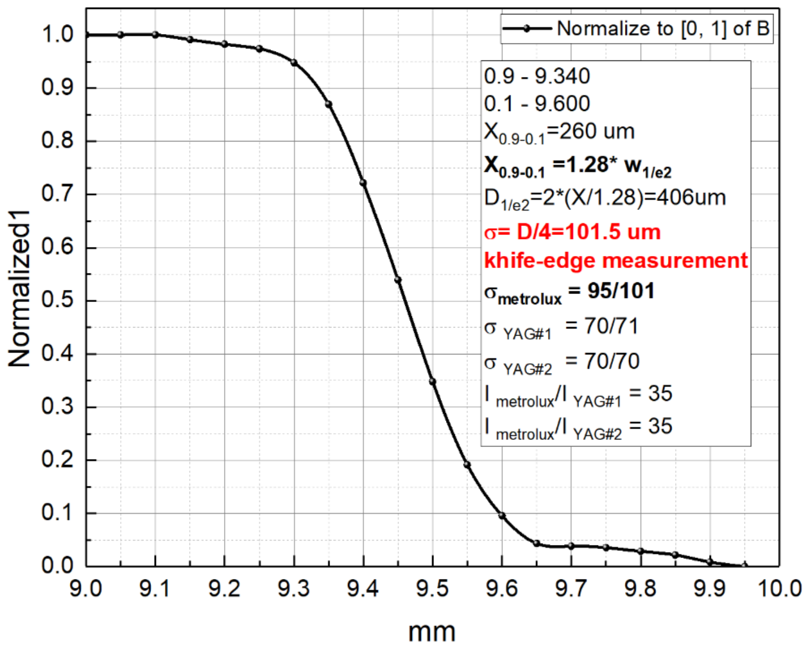
Bad overlap at center of modulator



Good overlap at center of modulator

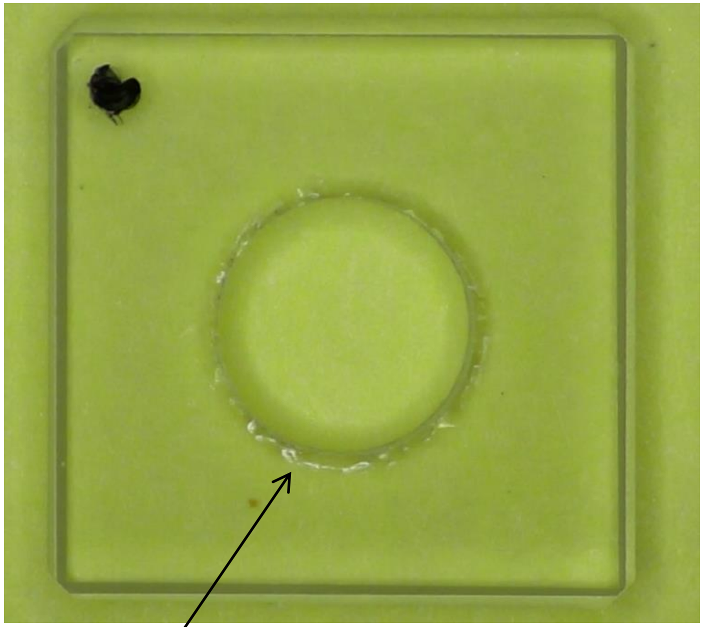
Experience: UV laser profile YAG:Ce vs Metrolux k6

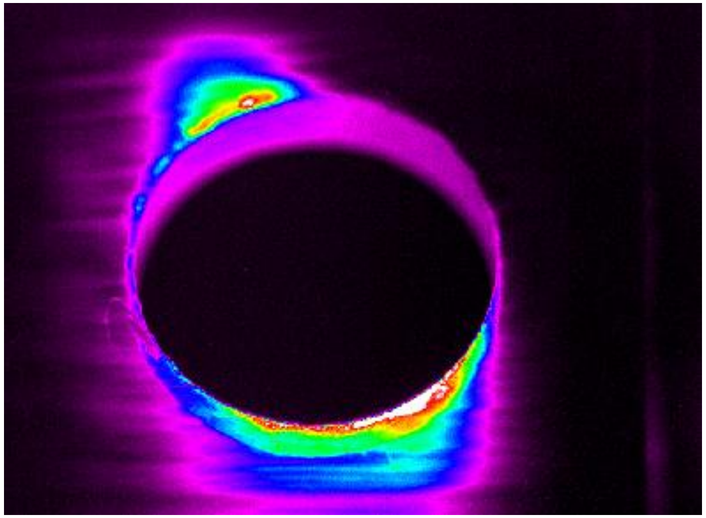
For UV laser @260nm
YAG:Ce underestimates beam size ~30% vs Metrolux K6
Confirmed by knife edge measurement



Metrolux K6: Refractive index: 1,69 Type: Fluorescence Wavelength: 150 nm - 360 nm Decay Time: 4,5 ms Emission Peak: 542 nm

Application: seed laser transverse position feedback

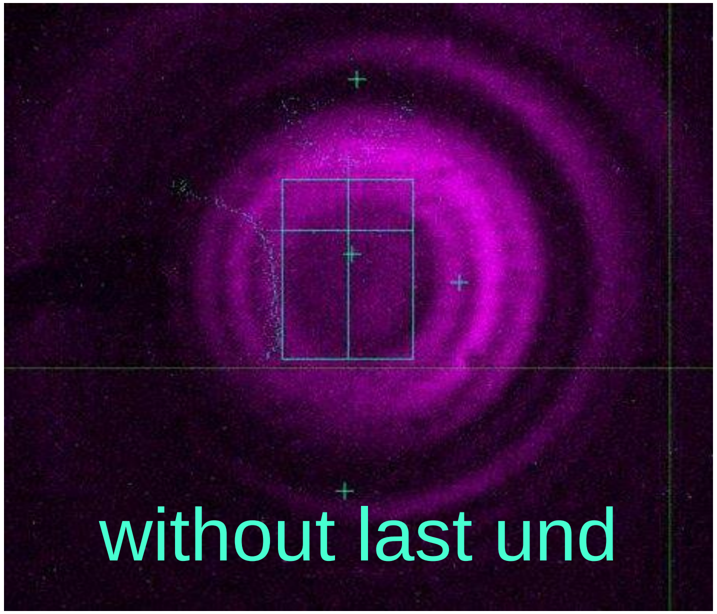


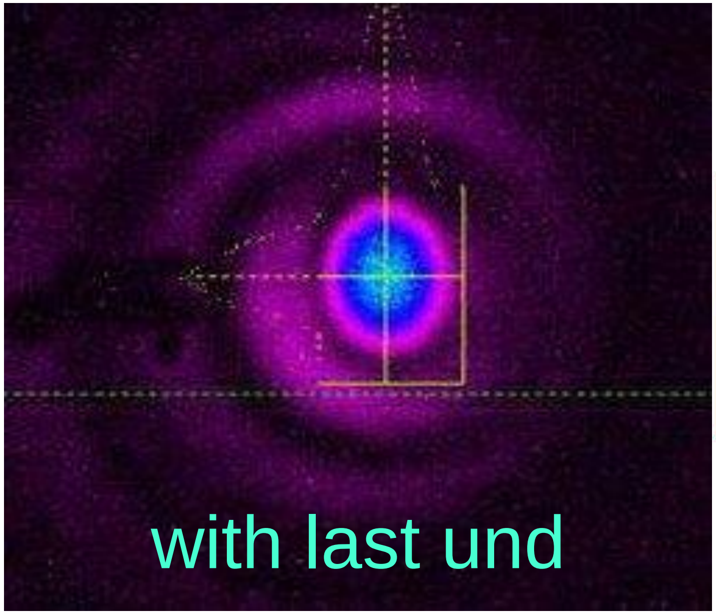


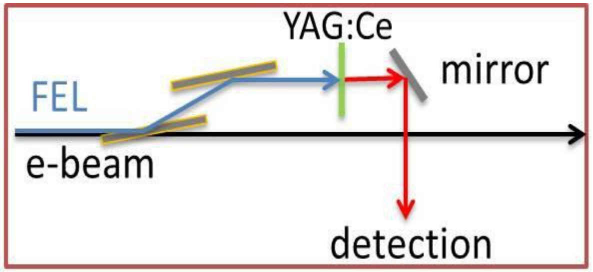
Metrolux K6 UV scintillator, 3mm thick, hole with 4.3 mm diameter
Note: e-beam and FEL pass inside hole unperturbed.

INTRAUNDULATOR SCREENS

Application: imaging of FEL radiation







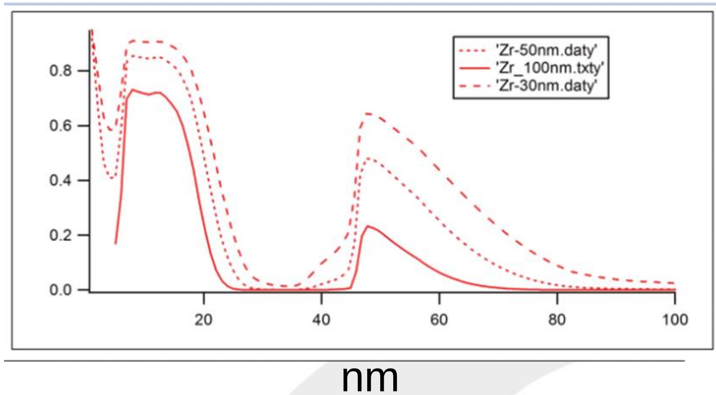
YAG:Ce + Al coating:

- suppress UV laser and COTR
- transmit radiation from FEL1 and FEL2 1st stage

YAG:Ce + Zr coating:

- suppress UV laser and COTR and FEL1 1st stage
- transmit radiation from FEL2 2nd stage

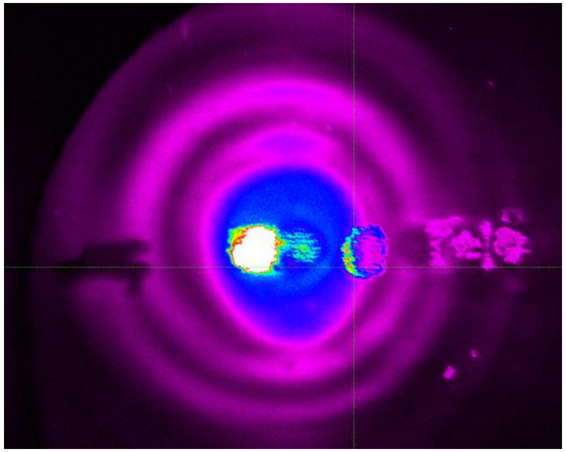
Zr transmission



INTRAUNDULATOR SCREENS

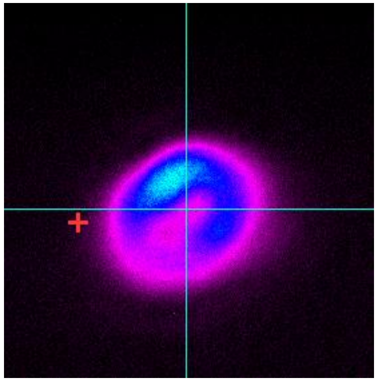
Experience: coating damage by FEL

FEL induced damage λ=32.6 nm
>50 μJ with round ~100μm beam (FWHM)

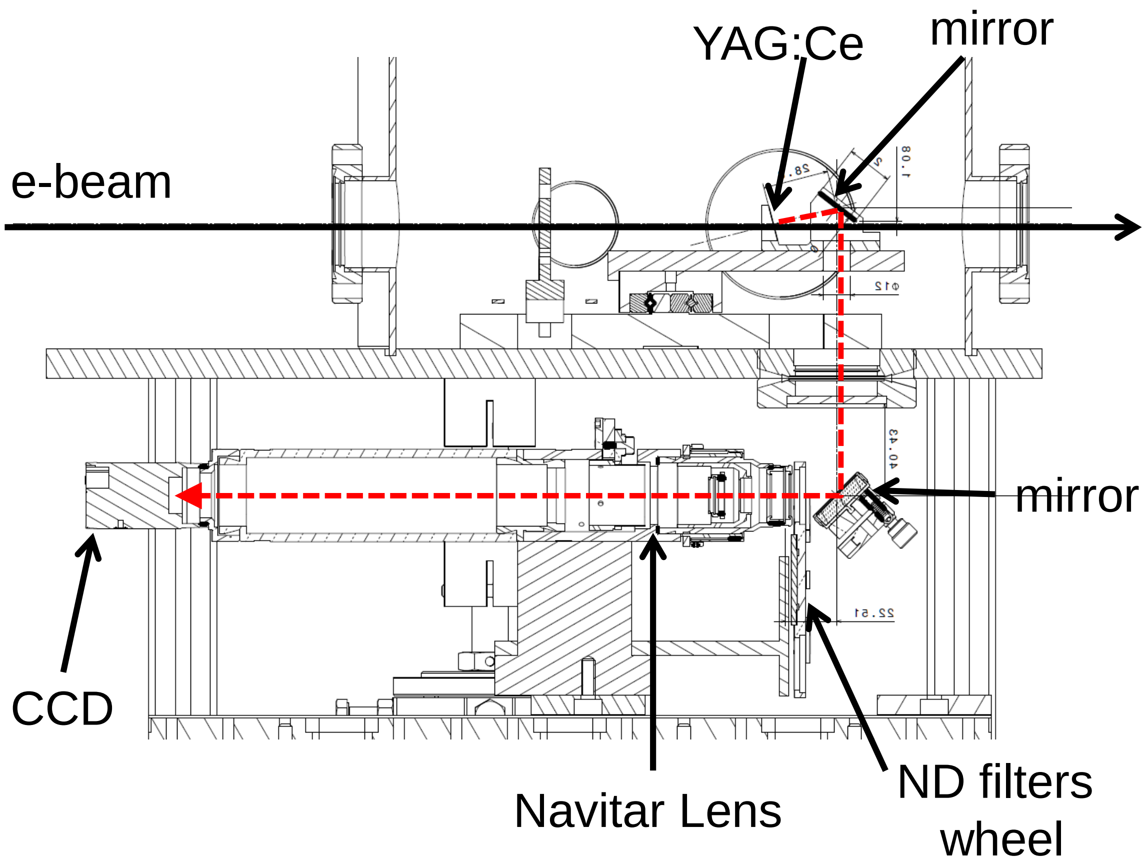


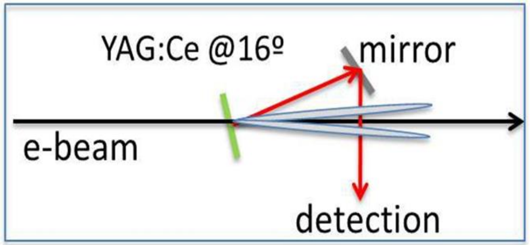
Experience: Zr coating has insufficient Optical Density

IR COTR passing through Zr coating
E~50 μJ with round ~100μm beam (FWHM)



New HYBRID MSCR-WIRESCANNER

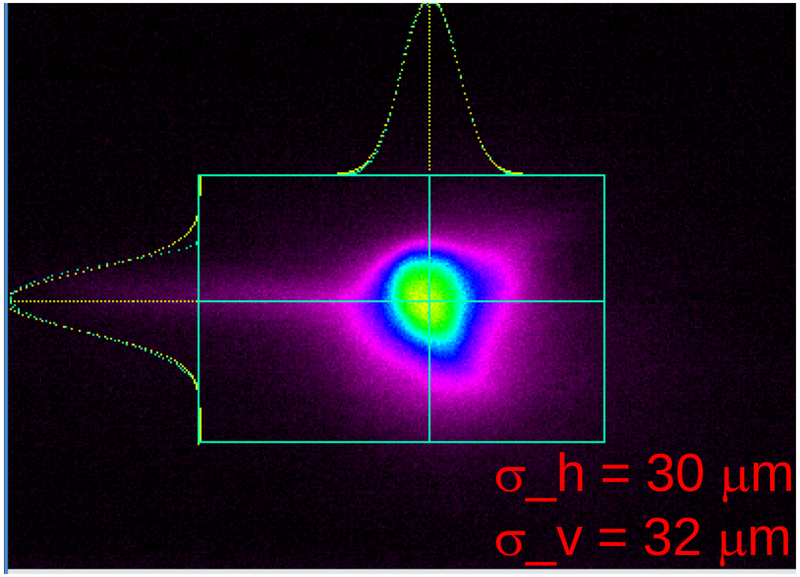




Horiz axis→ YAG:Ce with COTR immune geometry

(+ 45deg axis → wirescanner with two pairs of 10 μm tungsten wires inspired by experience with PSI WSC)

New: HYBRID MSCR-WIRESCANNER



Motorized lens (Navitar) focus +zoom

Horizontal setup
WD=175mm
→ Resolution 9 μm

Vertical setup (optional) WD=115 mm
→ Resolution 6 μm

Magnification: from 0.5 to 2.25
→ Lower mag. for RF deflector
→ Higher mag. for emittance measur.

The YAG:Ce contribution to the resolution is due to:

- refraction effects: refractive index and geometry
- saturation effects

G. Kube et al. IPAC10 MOPD088, (2010) + IPAC12 WEOAA02 (2012)
R. Ischebeck, et al. PRSTAB, 082802, (2015)
A.Murock et al. PAC2001 pg1334 (2001)

FUTURE UPGRADES

Upgrade Of Phase Space Screen in Diagnostic Beam Dump

Goal: increasing resolution, solving magnification and DOF issues, acquisition 50Hz full frame without complete redesign:

- → Telecentric lens
- → Scheimpflug geometry
- → CMOS camera 4000x2000px 10GbE (EVT)

Upgrade Of Emittance Measurement Screen In BC1

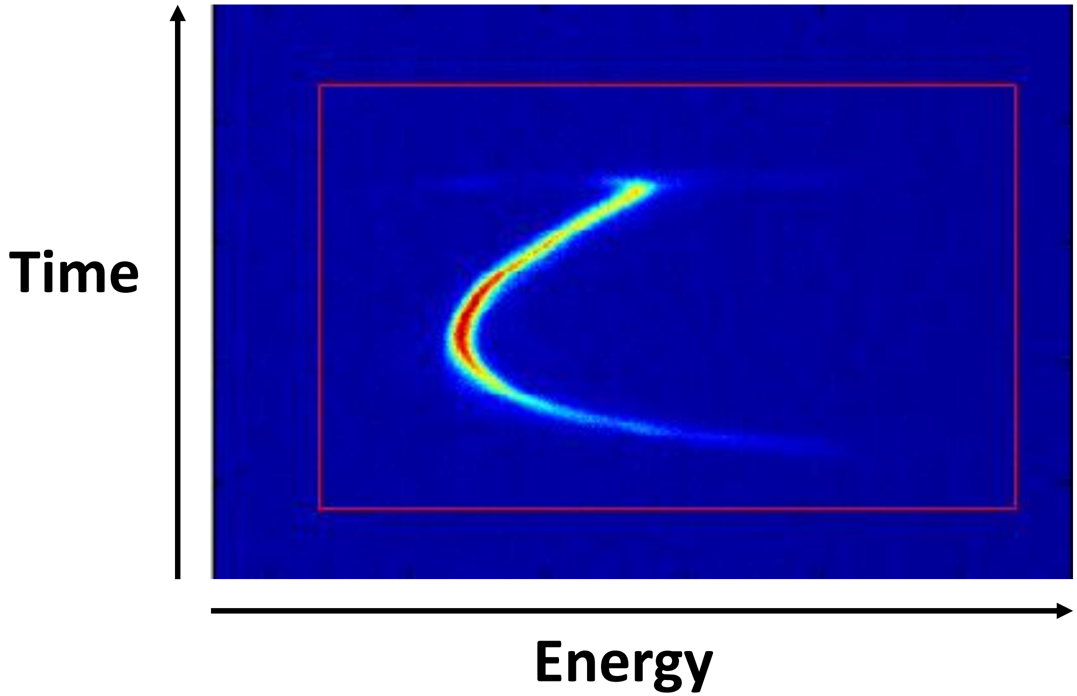
- → Goal increasing resolution

Upgrade Of Emittance Measurement Screen In LH

- → Goal increasing resolution

PHASE SPACE SCREEN

Longitudinal phase space measurement



With RF-Deflector + bending

e-beam area:

Horiz. ~ 20 mm
Vert. ~ 10mm

With Bending only

e-beam area:

Horiz. ~ 45 mm
Vert. ~0.2 mm

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PHASE SPACE SCREEN

45deg screen + normal lens →

SETUP

FIXED FOCAL LENGTH LENS

magnification is not constant on FOV

TELECENTRIC LENS

magnification is constant on FOV

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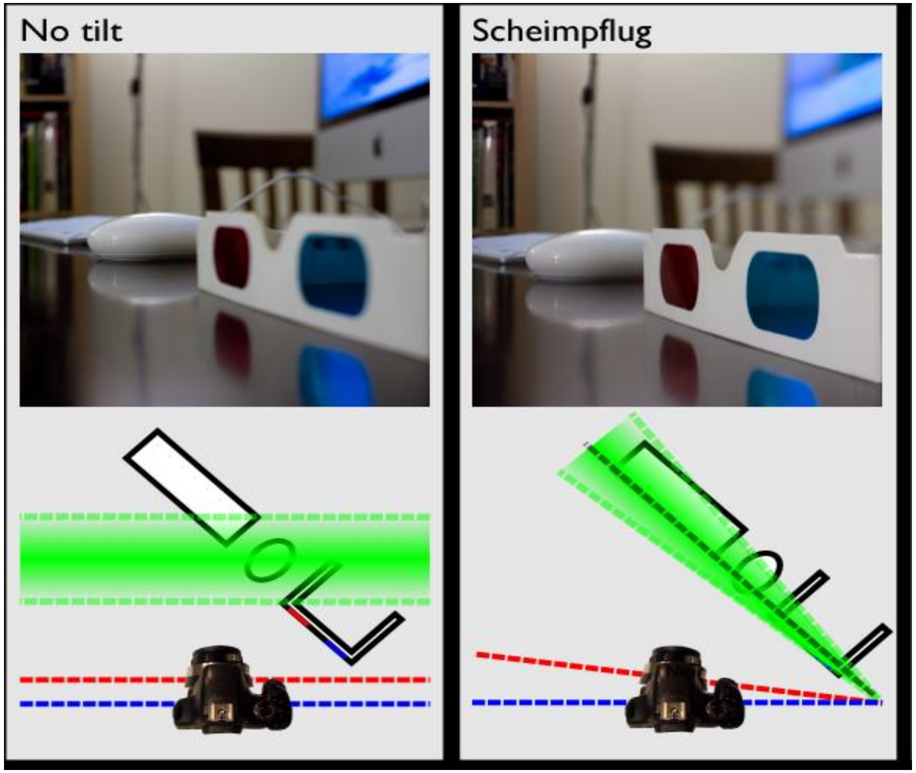
PHASE SPACE SCREEN

Target Depth of field = 45mm

e.g. focal length 100 mm macro lens at F#8, WD 0,5m →DOF<10mm



Scheimpflug principle

Two approaches:

1) Tilt shift lens
2) **Straight lens, tilted sensor**

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CONCLUSIONS

- ✓ From BC1 onwards COTR makes OTR screens not usable for profile measurements → scintillation screens
- ✓ Redesign of intra undulator screens with COTR immune geometry.
- ✓ E-beam vs seed laser transverse alignment with YAG:Ce
- ✓ Seed laser (260nm) beam size use UV scintillator not YAG:Ce
- ✓ Seed laser pointing stabilization with holey UV scintillator
- ✓ FEL radiation detection with special setup Al/Zr coated YAG:Ce. Damage 50-100 μJ
- ✓ New hybrid MSCR-wirescanner under commissioning
- ✓ 3 major screen upgrades in near future

TEAM

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Thank you!

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