Investigations into the new infrared undulator as bunch diagnostic tool

Arik Willner
Universität Hamburg

FLASH Seminar
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Overview

- Motivation
- The Undulator
- The experimental set-up
- Results
- Conclusion and Outlook

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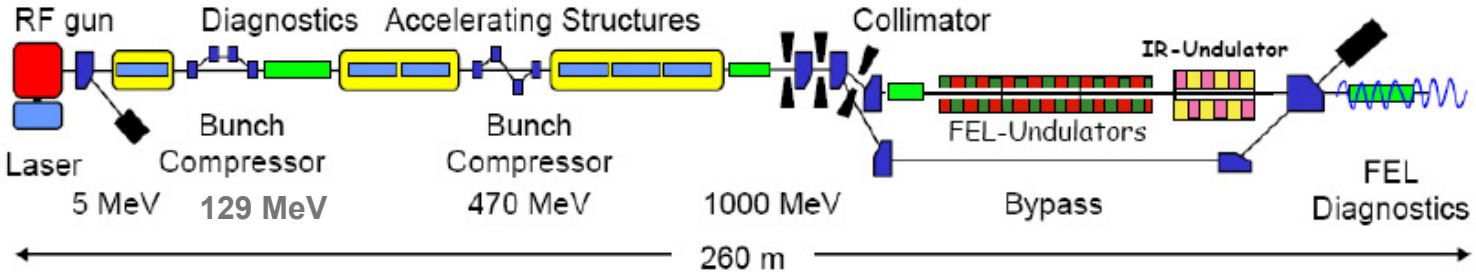
Motivation



- new infrared undulator after FEL at FLASH (Free-Electron-Laser in Hamburg)
- plan: IR-undulator uses same bunches as FEL parasiticly

Motivation

Application:

- longitudinal bunch reconstruction and bunch diagnostics
- Source for Pump-Probe experiments using synchronized VUV- and IR-Pulse

Motivation

Application:

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Far goal of experiments presented in this talk

Motivation

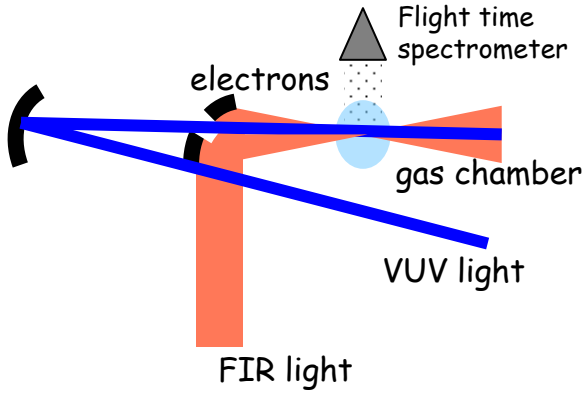
Application:

- longitudinal bunch reconstruction and bunch diagnostics
- Source for Pump-Probe experiments using synchronized VUV- and IR-Pulse

Short desciption:

- VUV-pulse and infrared pulse naturally synchronized – same bunch produces pulse in FEL and IR-undulator
- Investigation of FLASH pulse structure possible

… see talk of Ulrike Frühling



Motivation

Longitudinal bunch diagnostics

- Lasing in FEL is dependent on peak current of bunch

$$L_G = C \cdot \gamma \cdot \left(\frac{\sigma^2}{I_0} \right)$$

→ **THE LONGITUDINAL BUNCH SHAPE HAS TO BE INVESTIGATED!**

Motivation

Longitudinal bunch diagnostics

- Many groups are working on that using several techniques.
- BUT NONE OF THESE THECHNIQUES GAVE ALL INFORMATION NEEDED!
- Plus: Many questions occured with first results of bunch length measurements

→ New Ideas for longitudinal bunch shape diagnostics were developed…

Motivation

Usage of an infrared undulator as coherent diagnostic tool

- One type of diagnostic: *coherent diagnostic in frequency domain*

Coherent spectrum ➔ Formfactor ➔ Charge distribution

$$I(\omega) = I_1(\omega) \cdot \left(N + N(N+1)\left|F(\omega)\right|^2\right)$$

mathematical construction

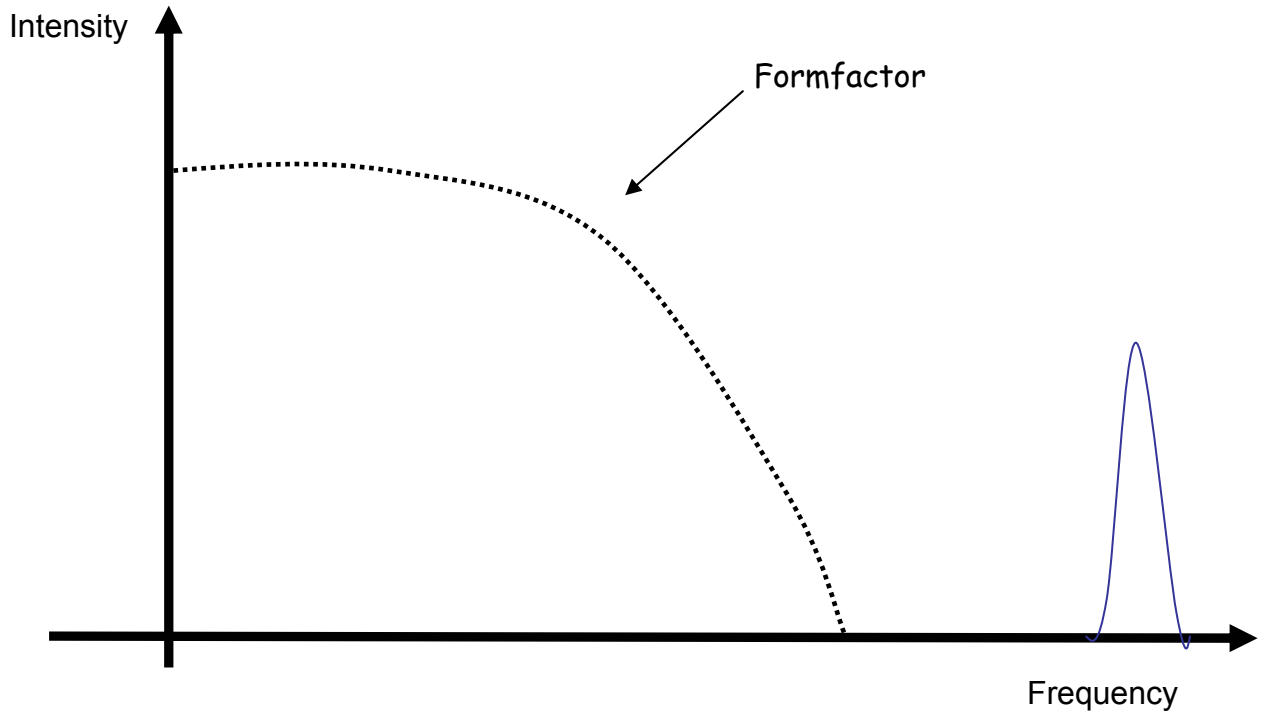
$$F(\omega)$$

Fourier transform

$$\rho(r)$$

Motivation

Idea with Undulator: Tune through wavelengths and measure Intensity!



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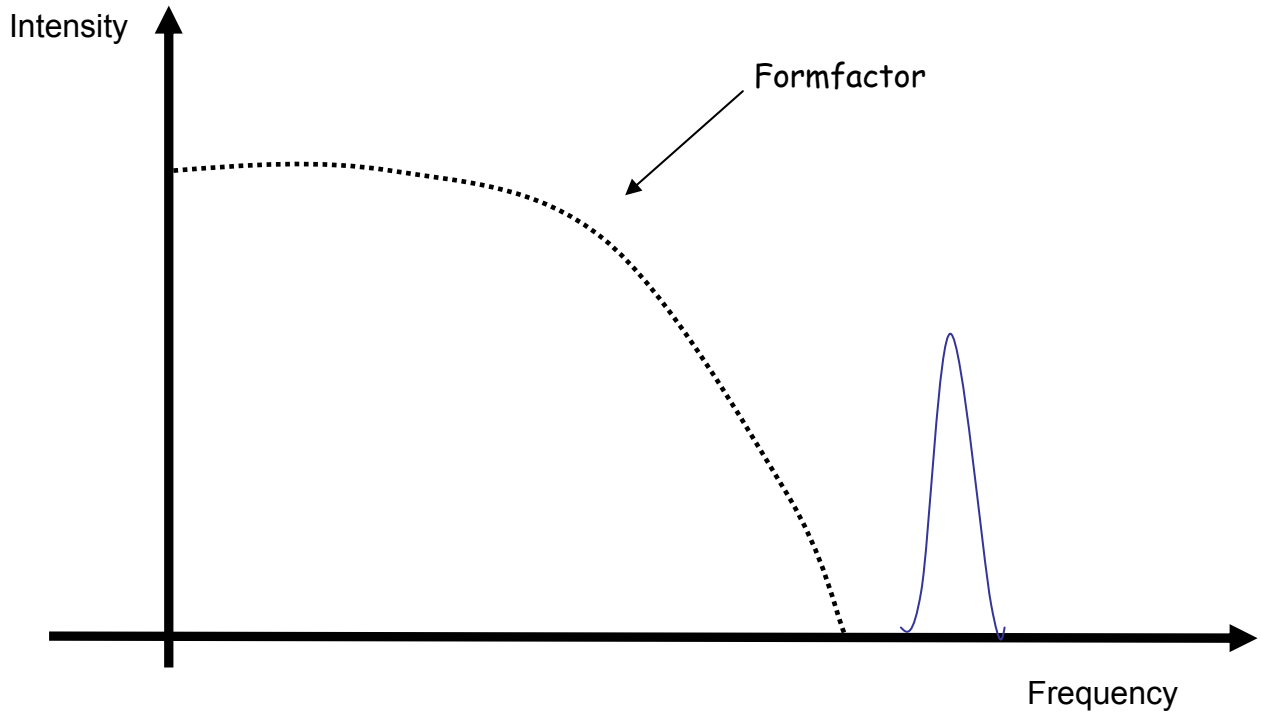

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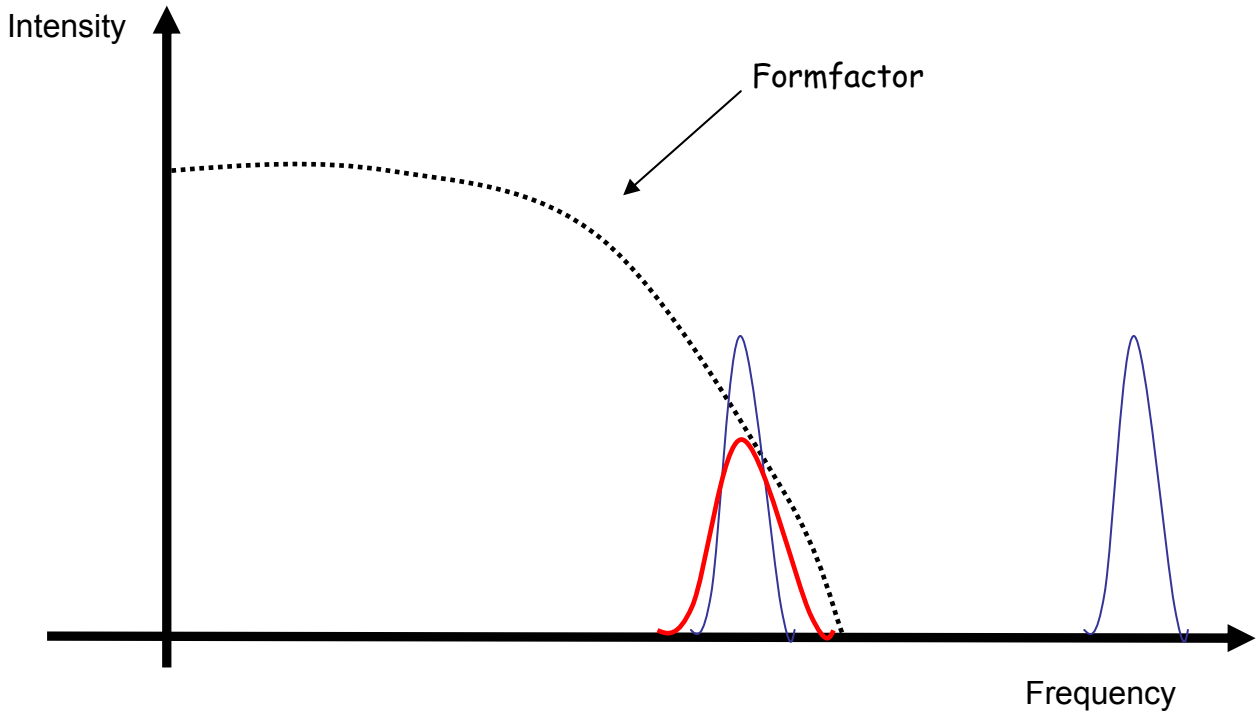

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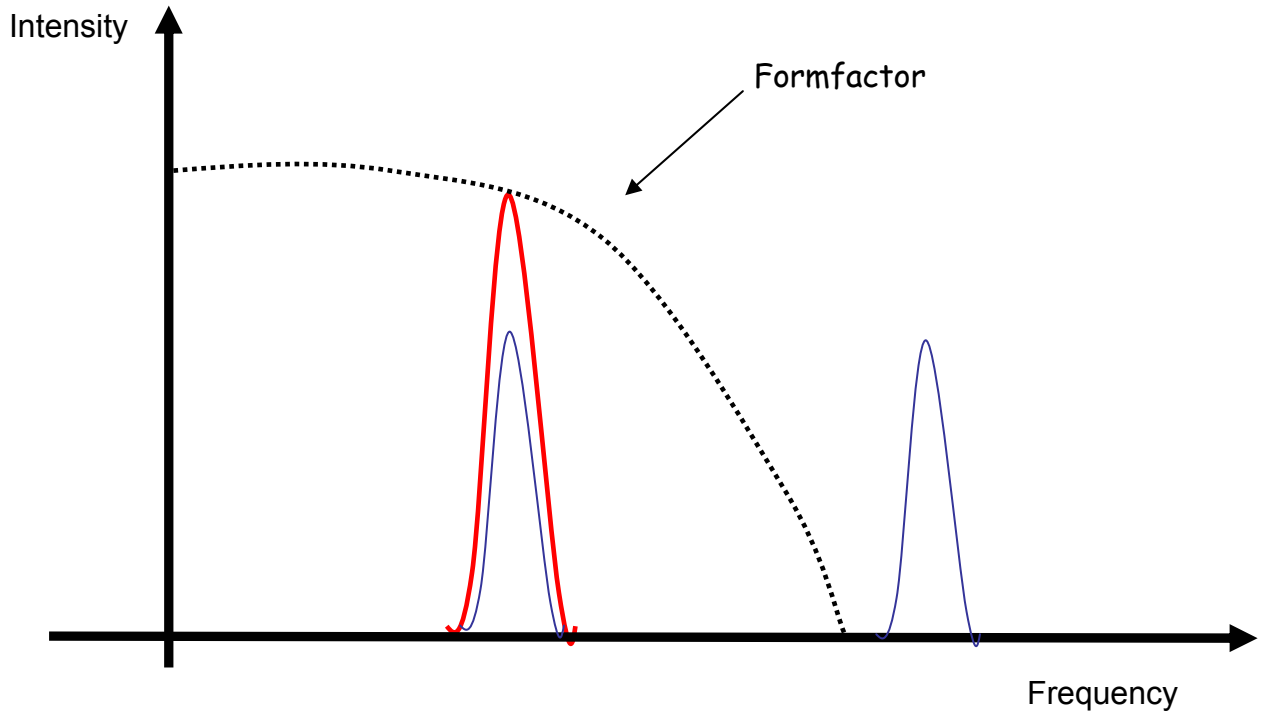

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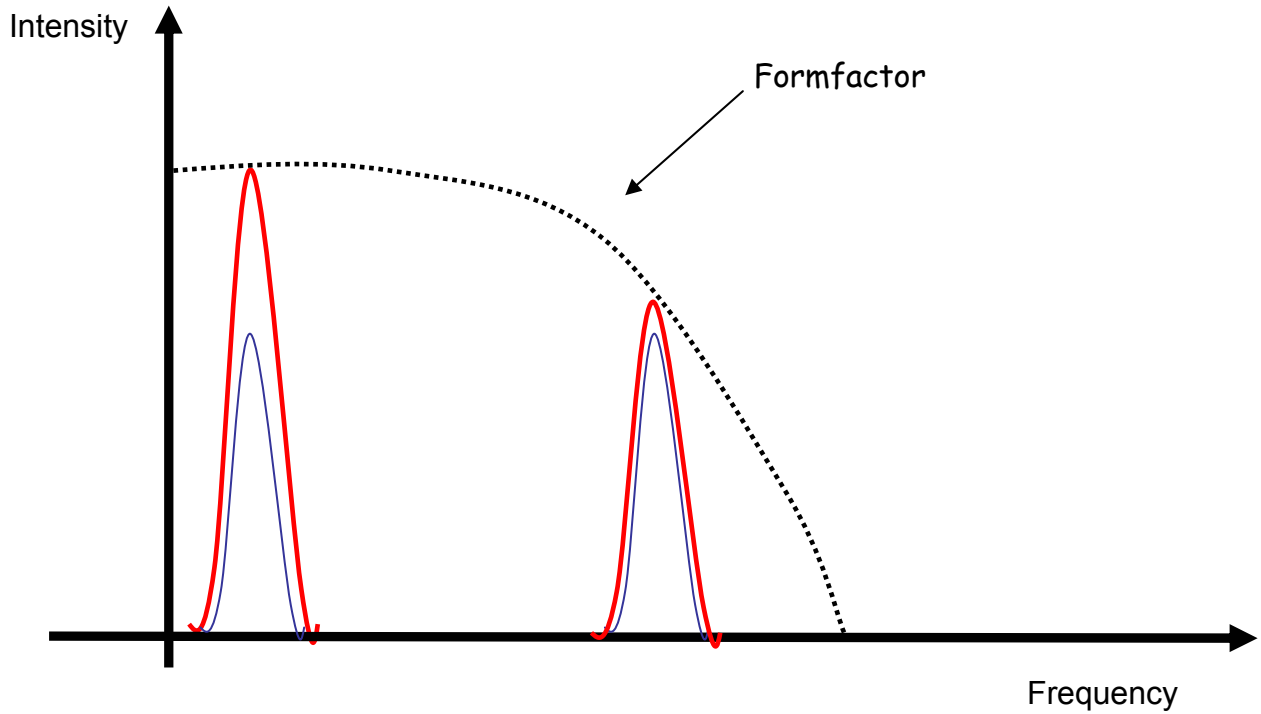

Motivation

BUT: WAY BEFORE ONE NEEDS A GOOD UNDERSTANDING OF SPECTRUM!

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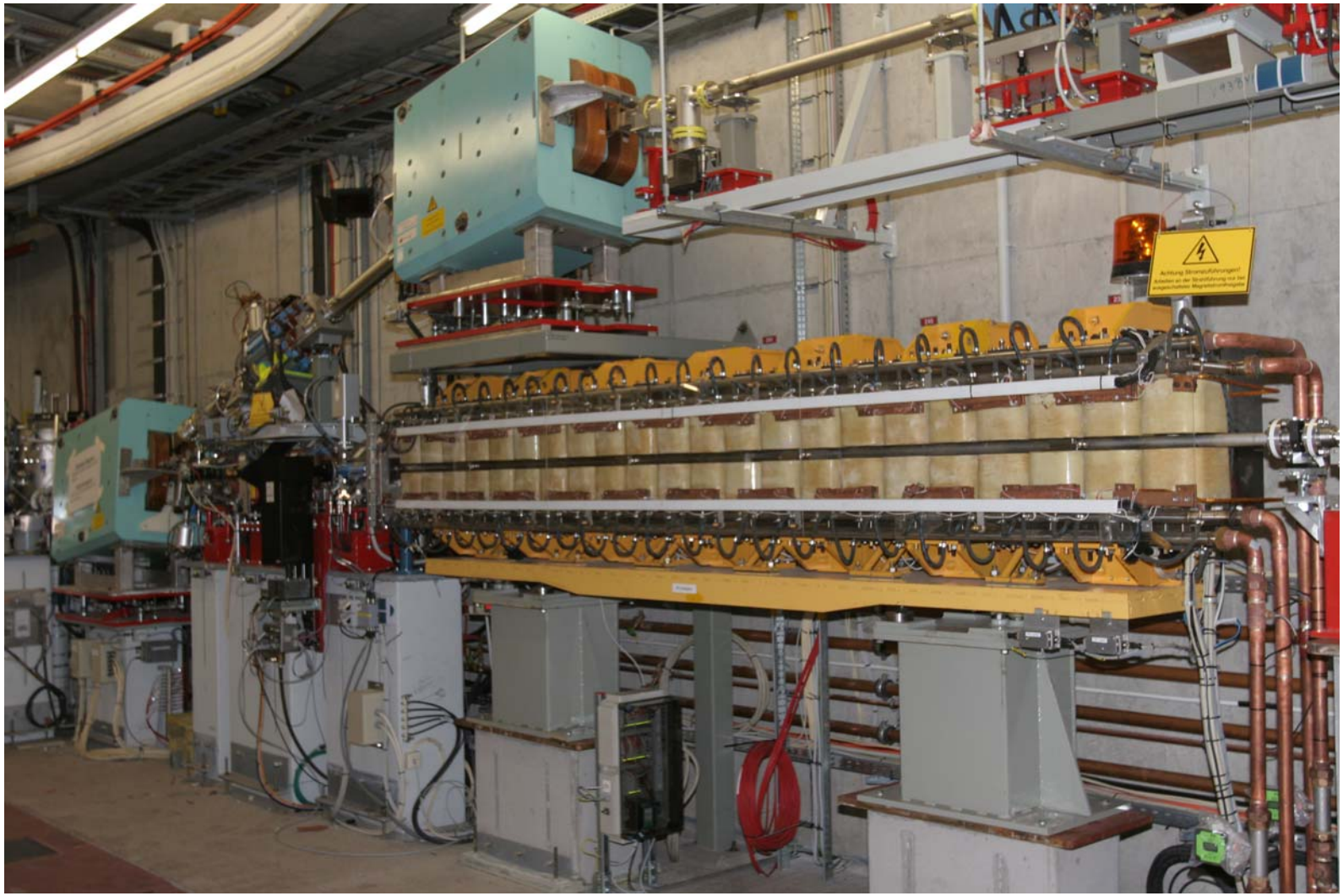
IR Undulator



IR Undulator

Type : electromagnetic

K-Value : 1 - 44

Range : 1 - 200µm at FLASH energy 500MeV

#Periods : 9 full

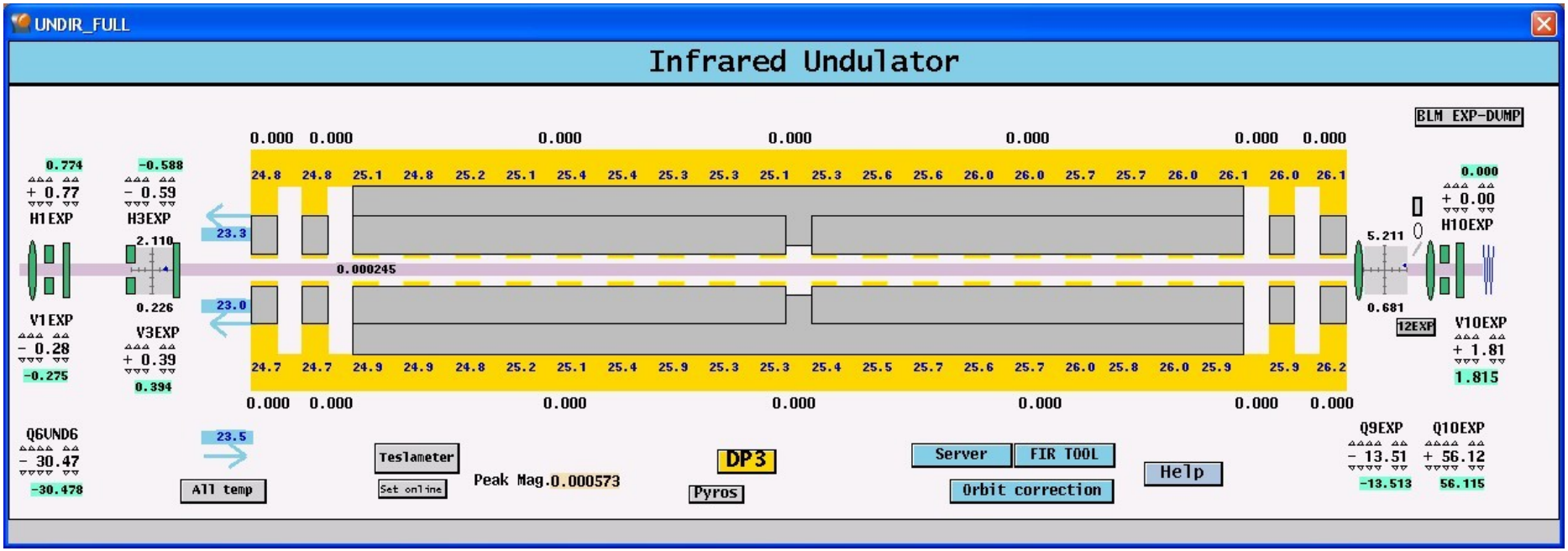
Period length: 40cm

Gap : 40mm

Max. Current: 435A

Max Field : 1.2T

IR Undulator



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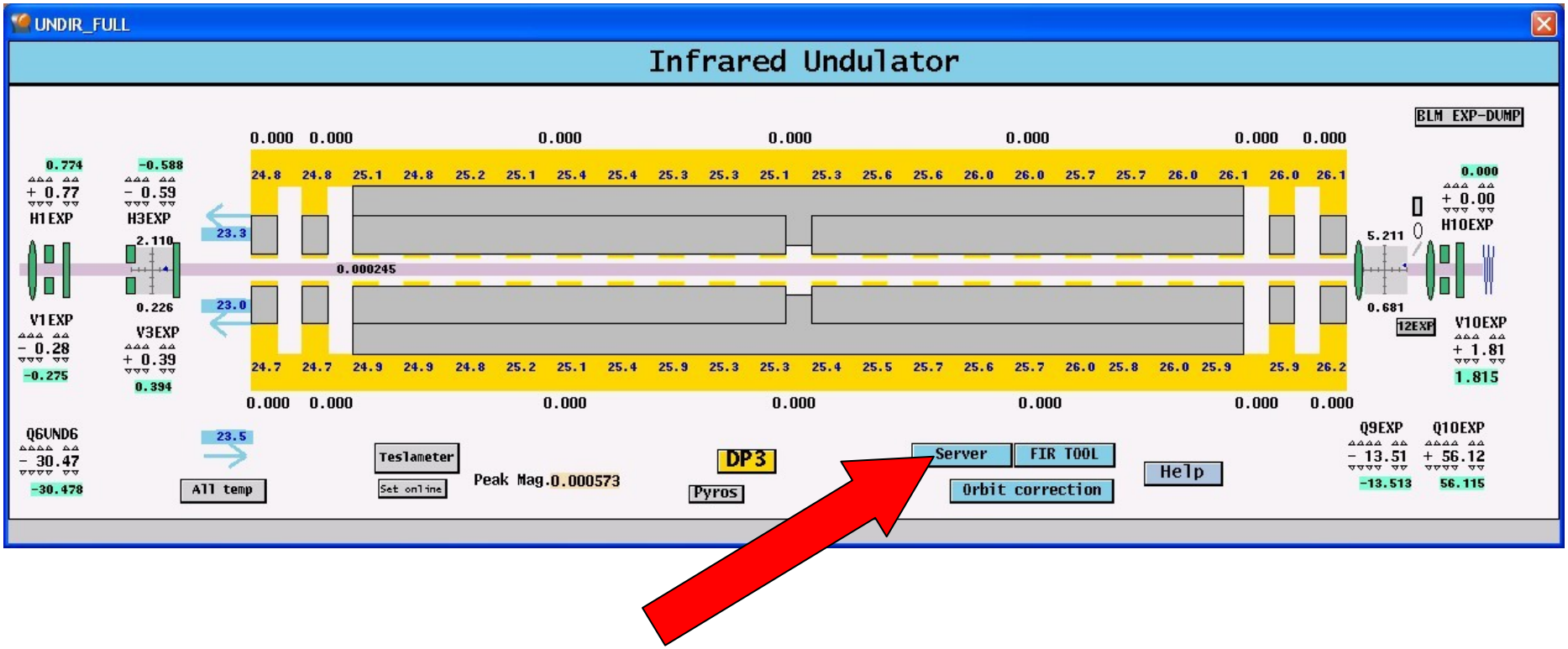

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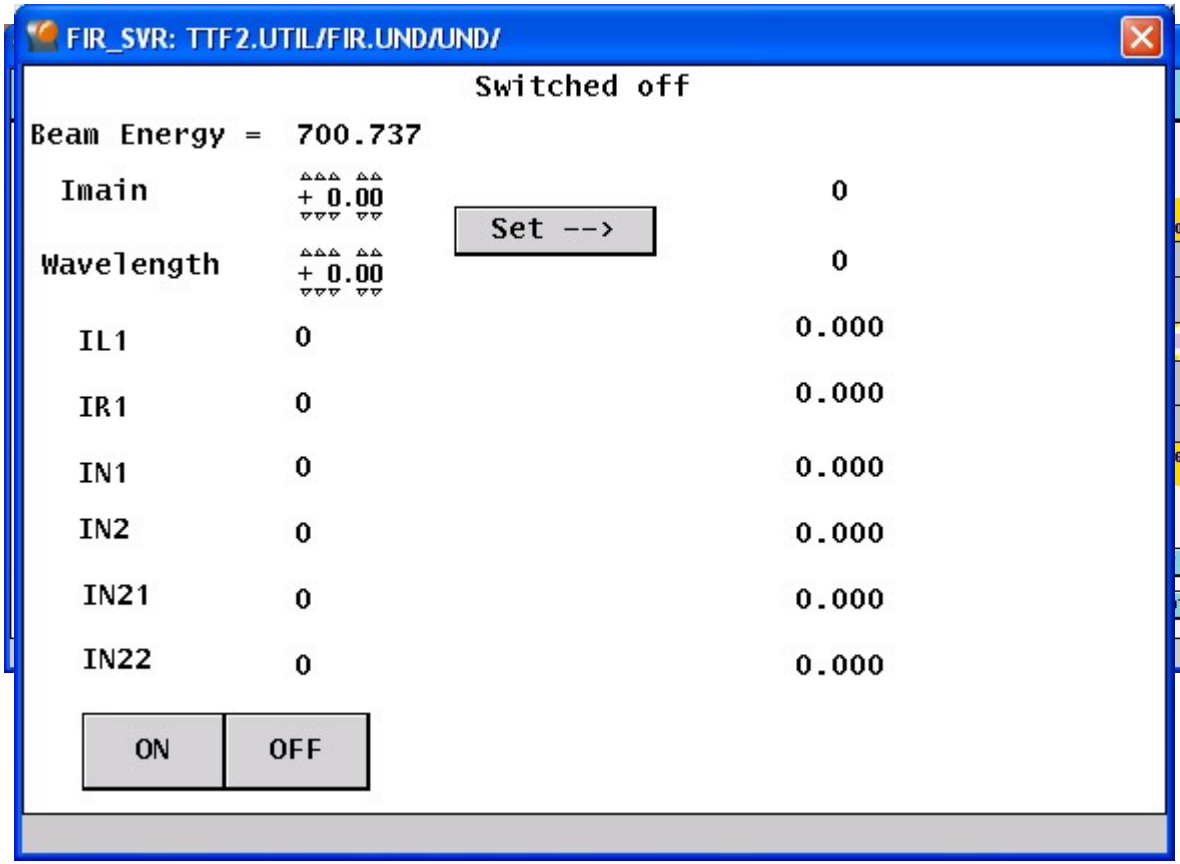

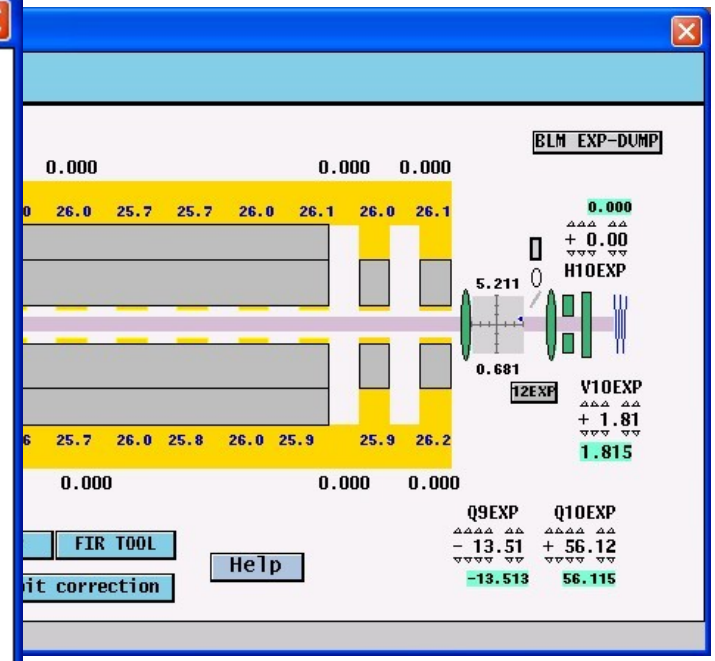

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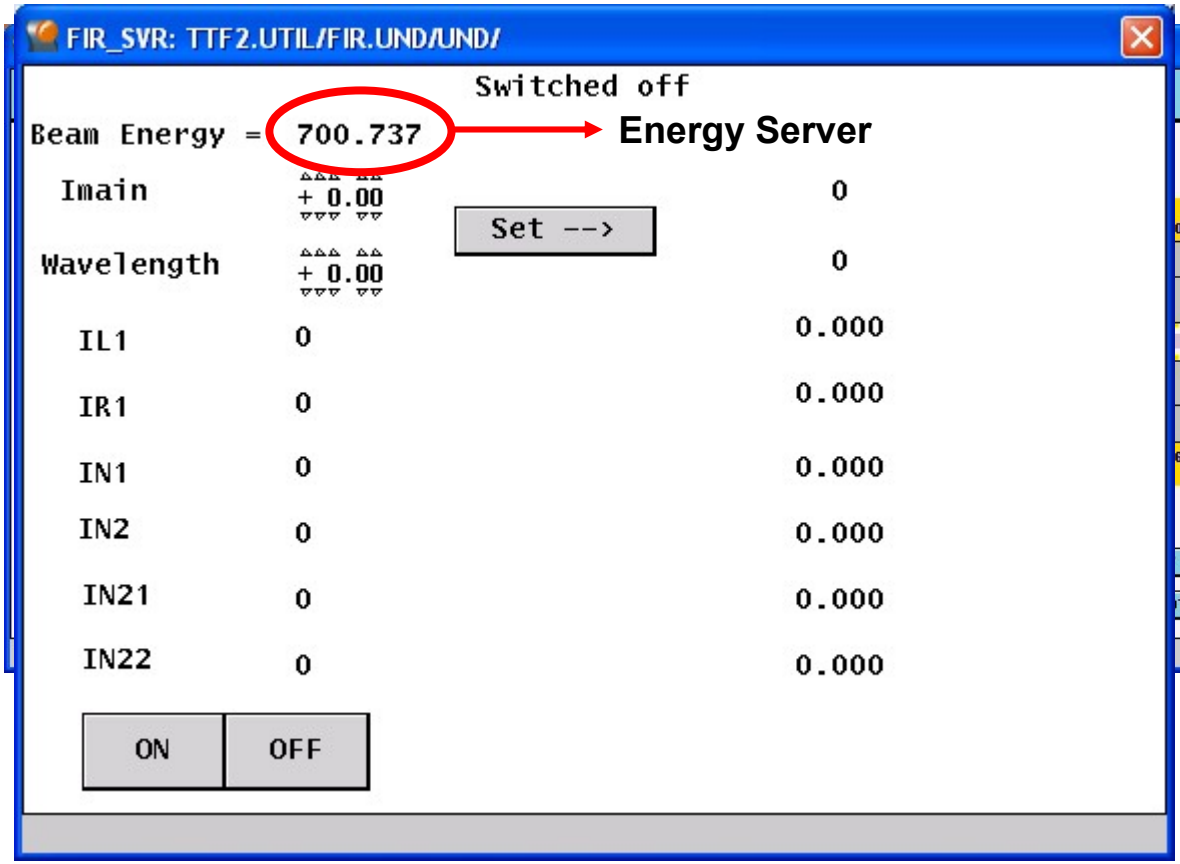

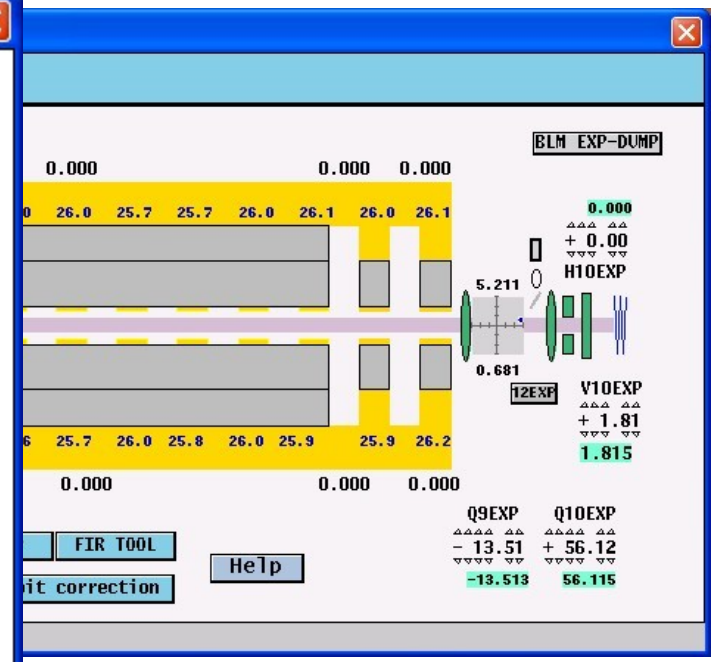

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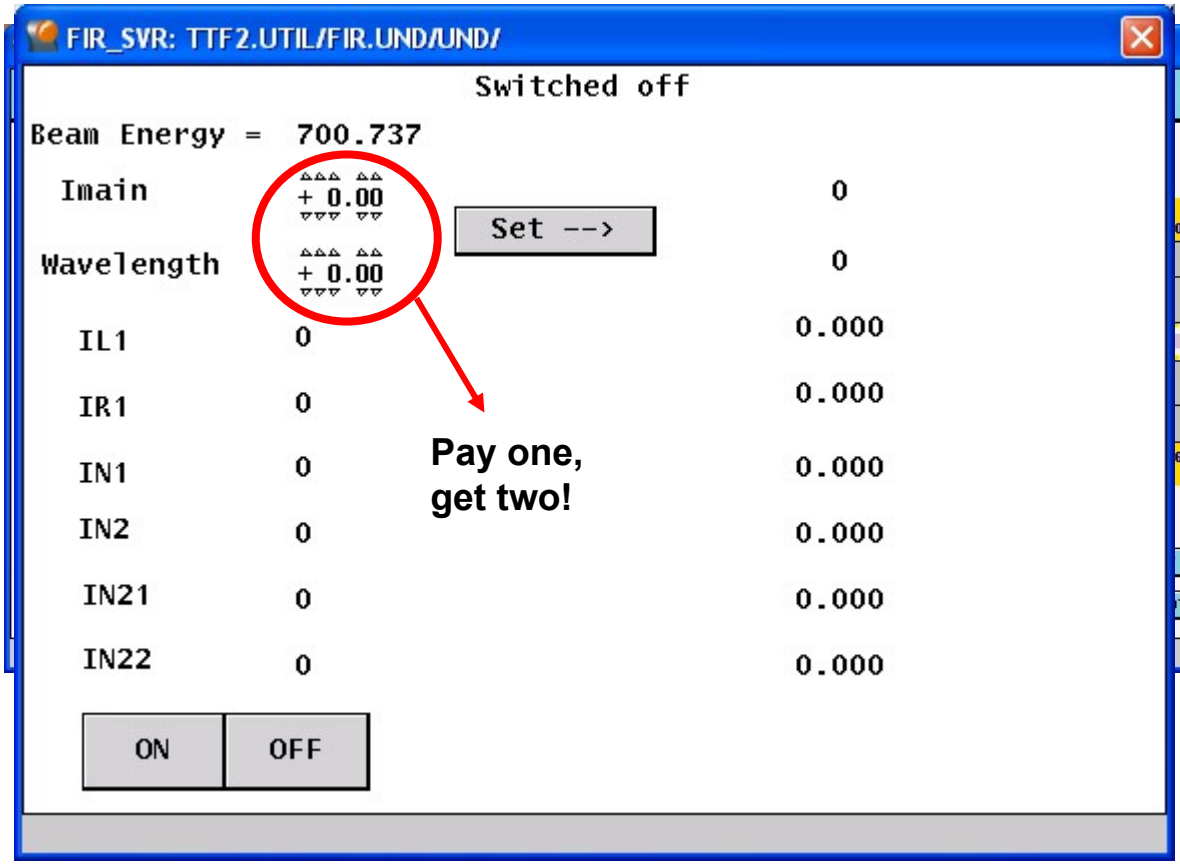

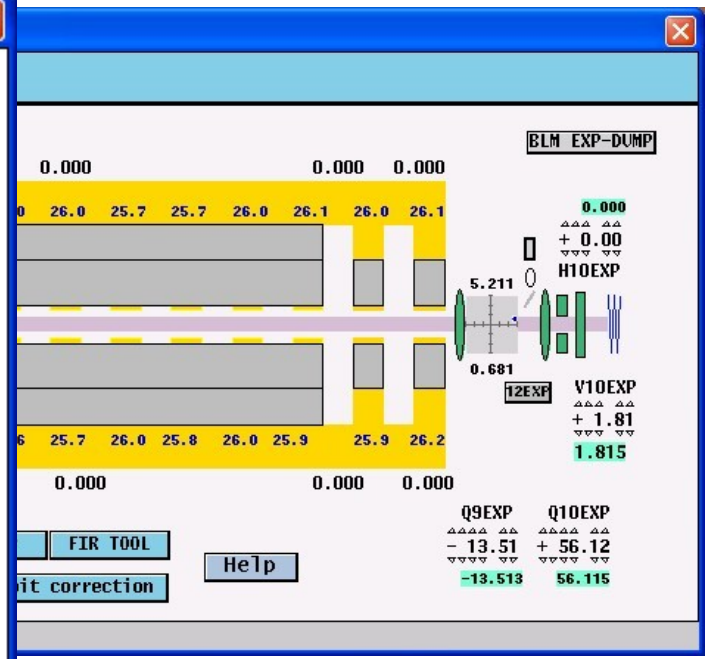

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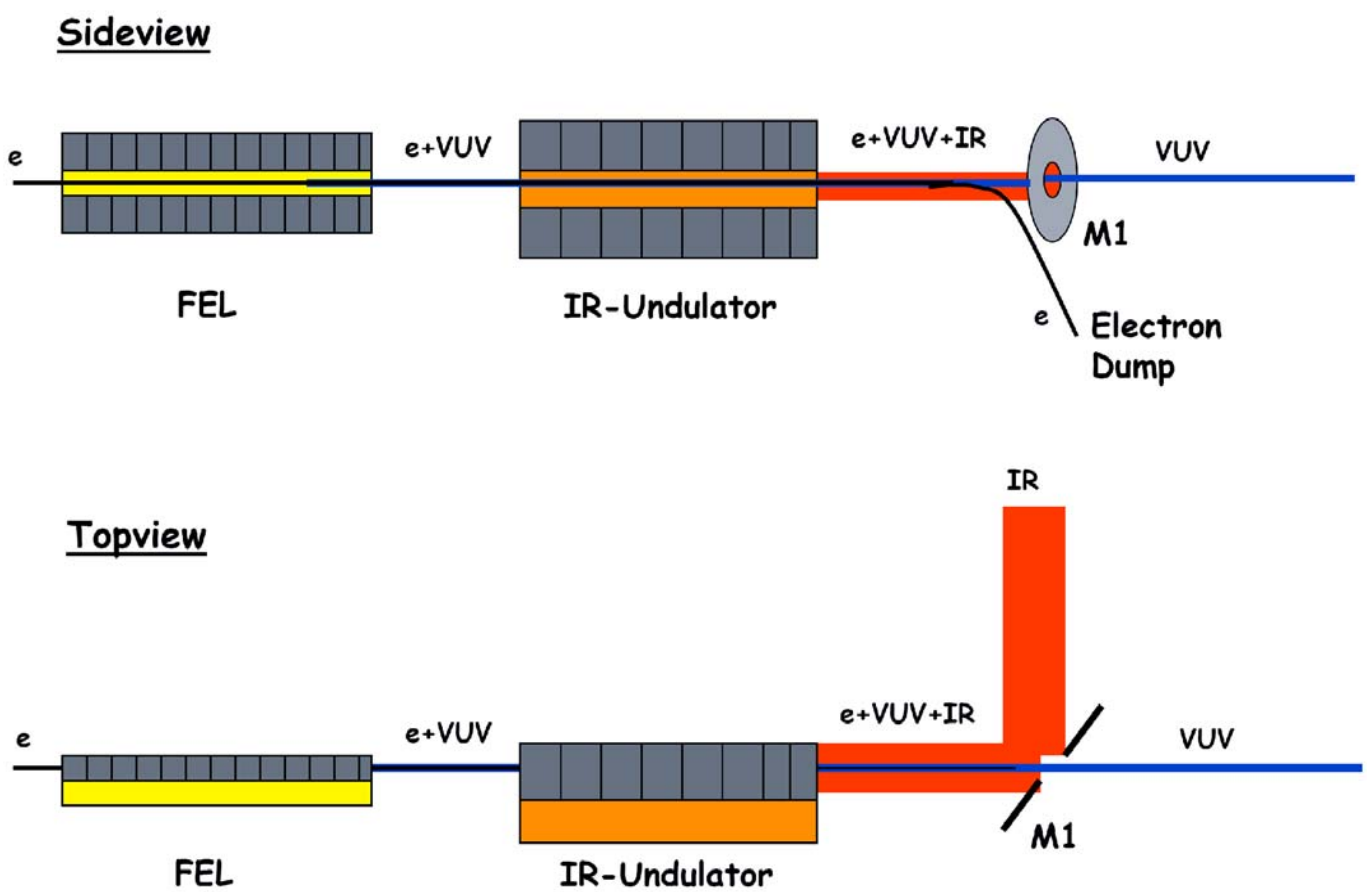

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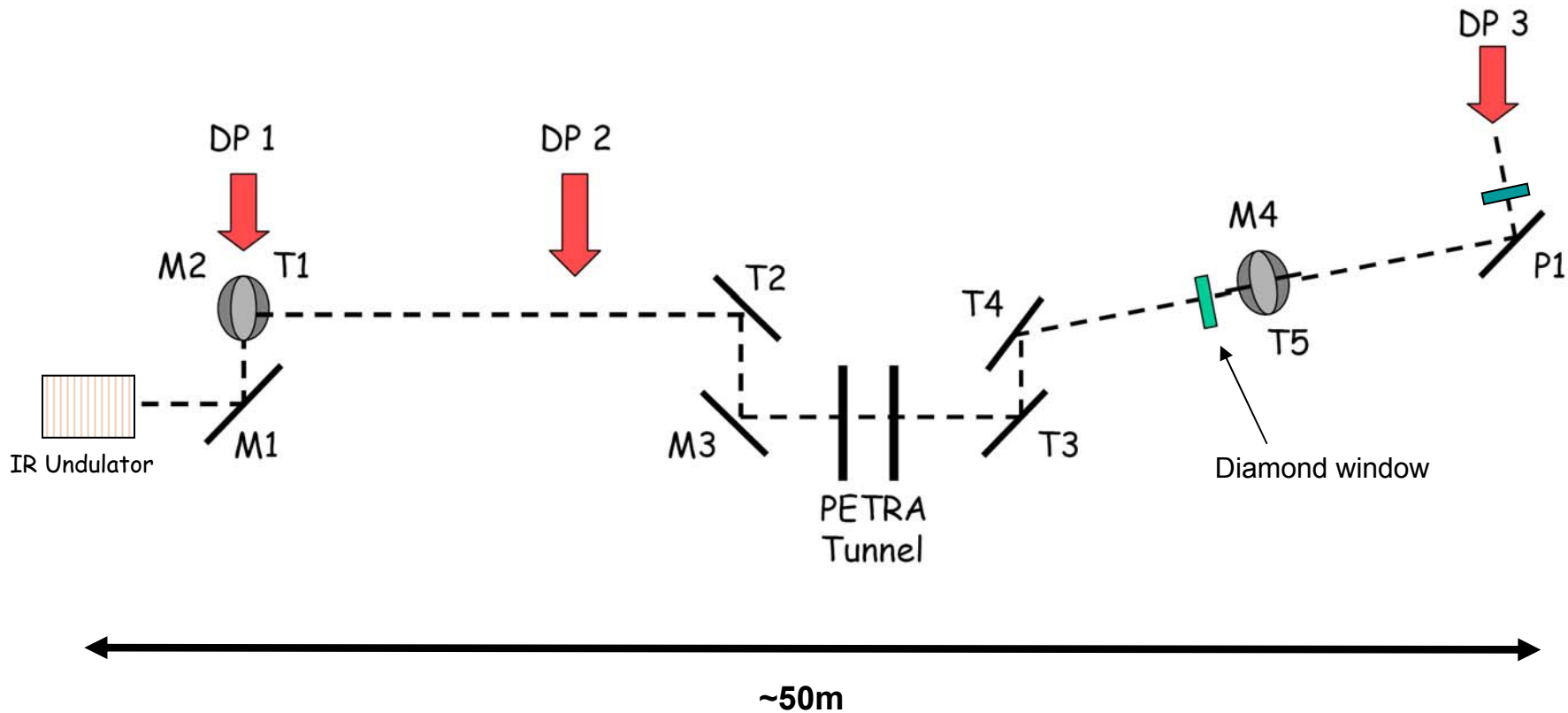

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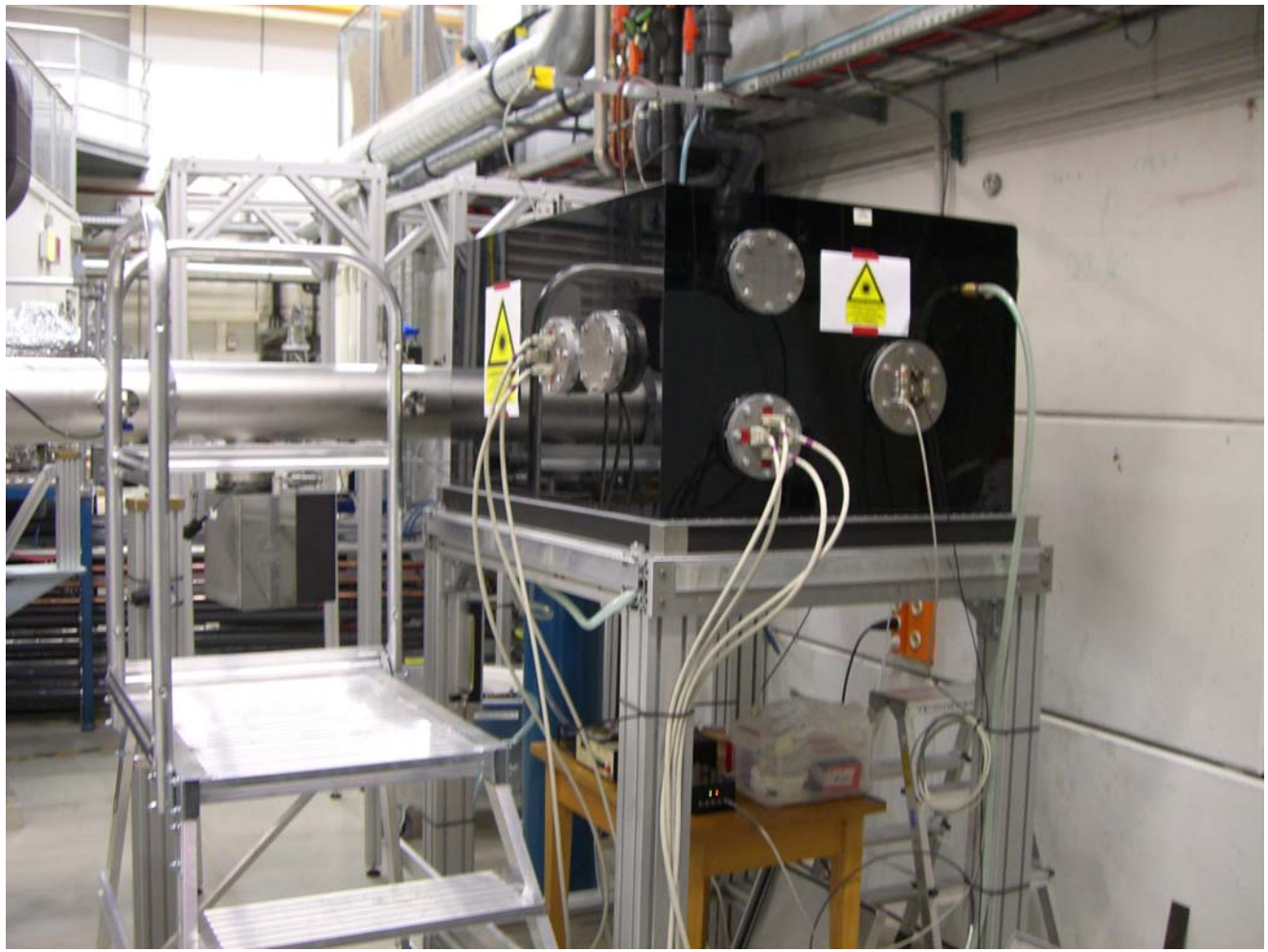

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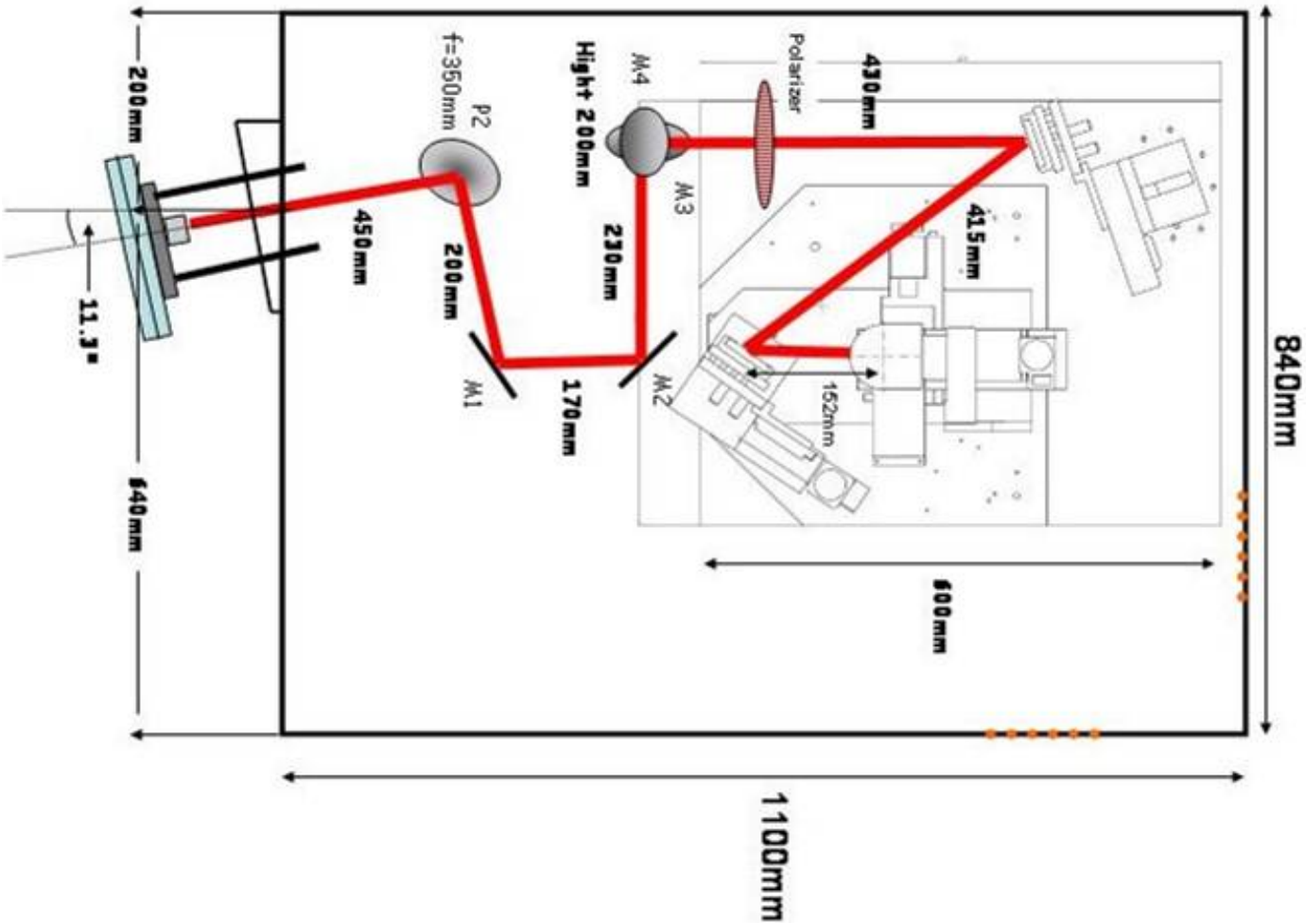

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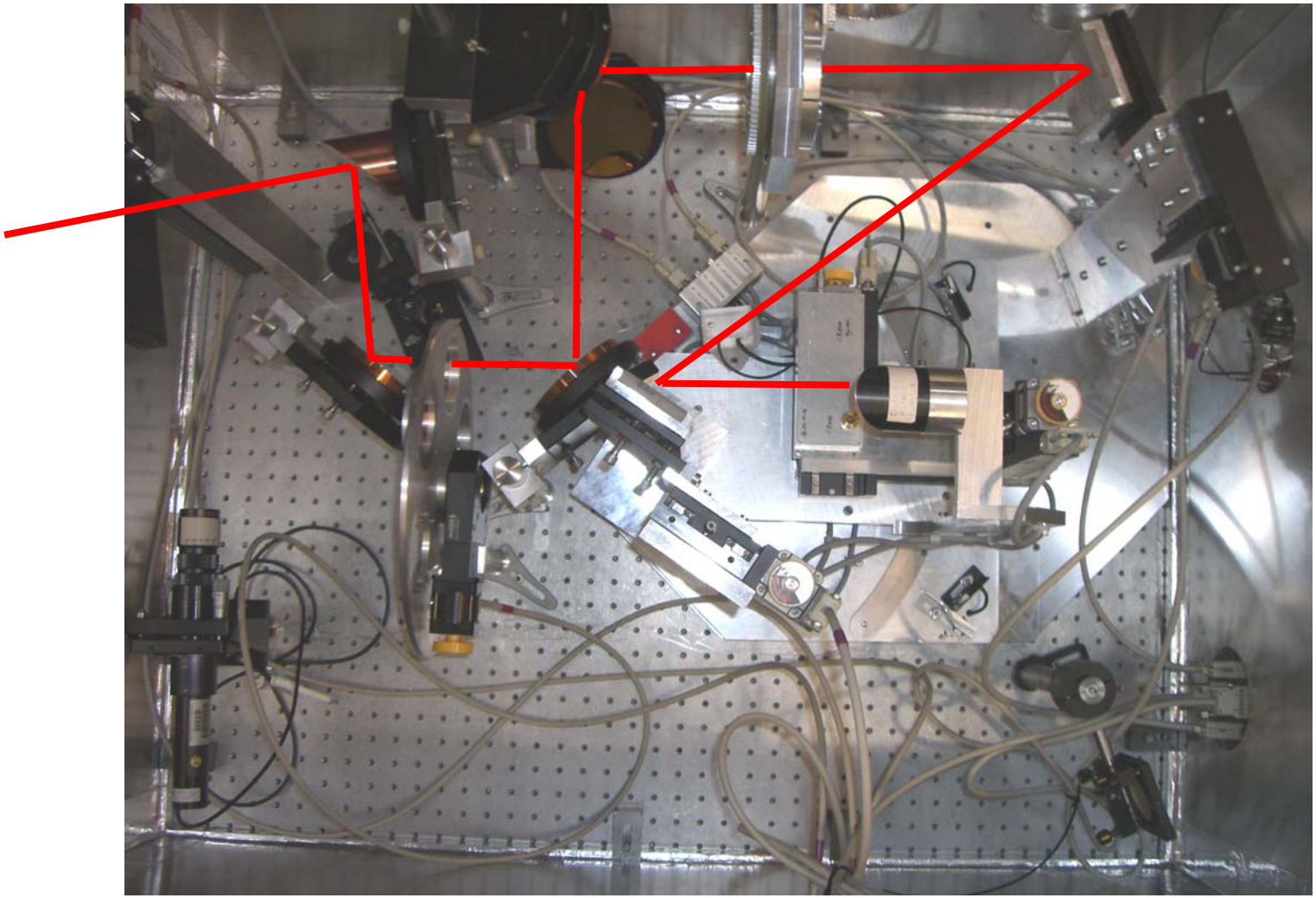

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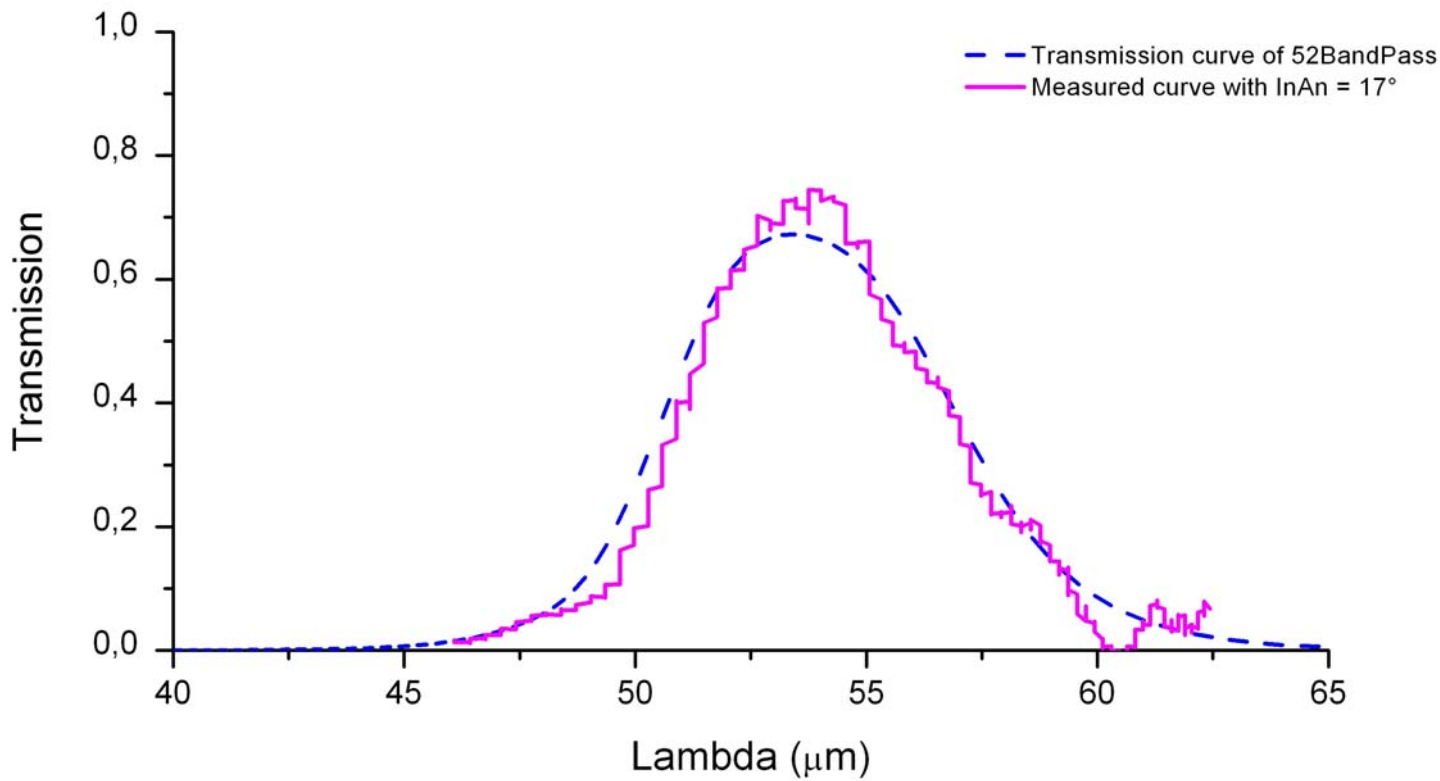
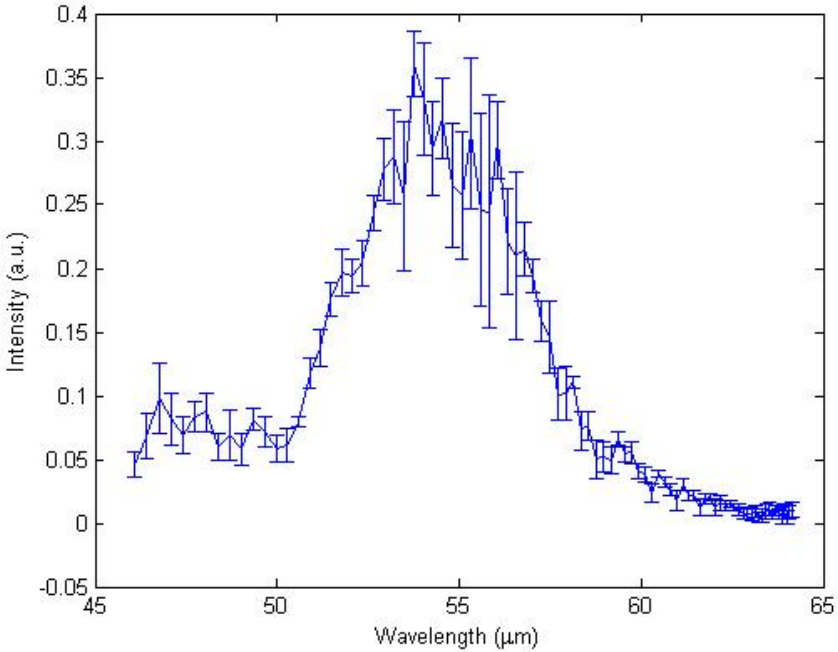
Results

Wavelength calibration

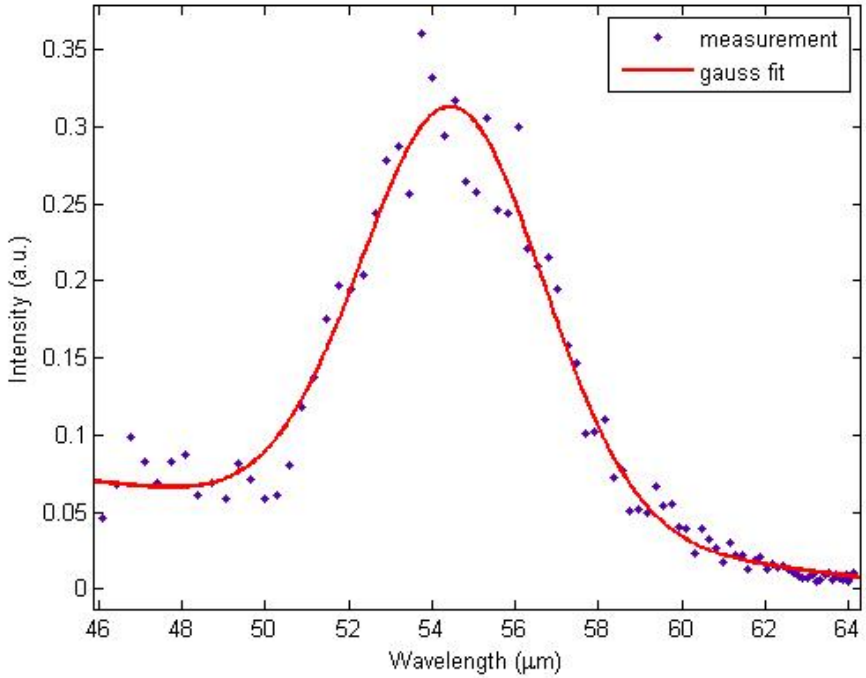


Results

Wavelength shift



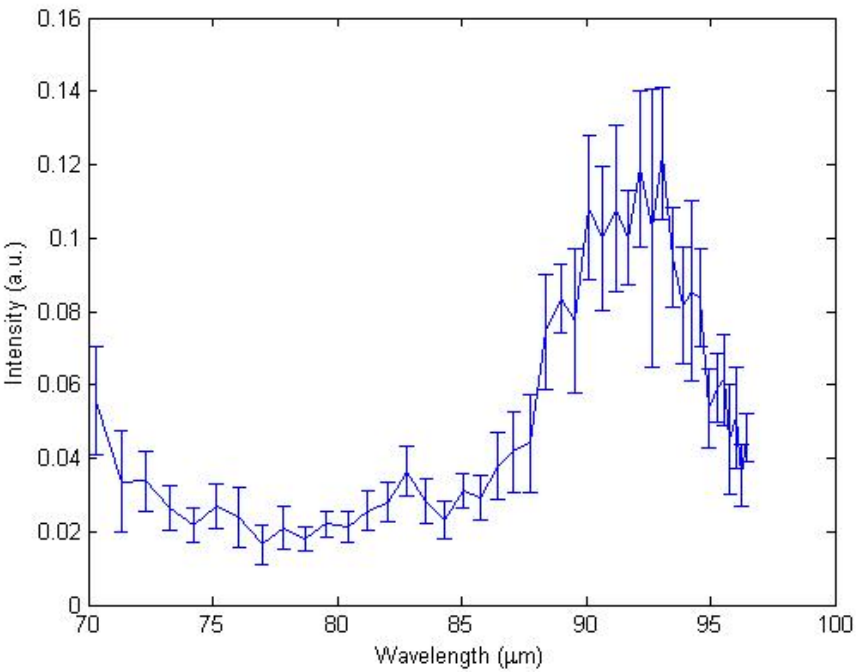
Undulator at 50µm



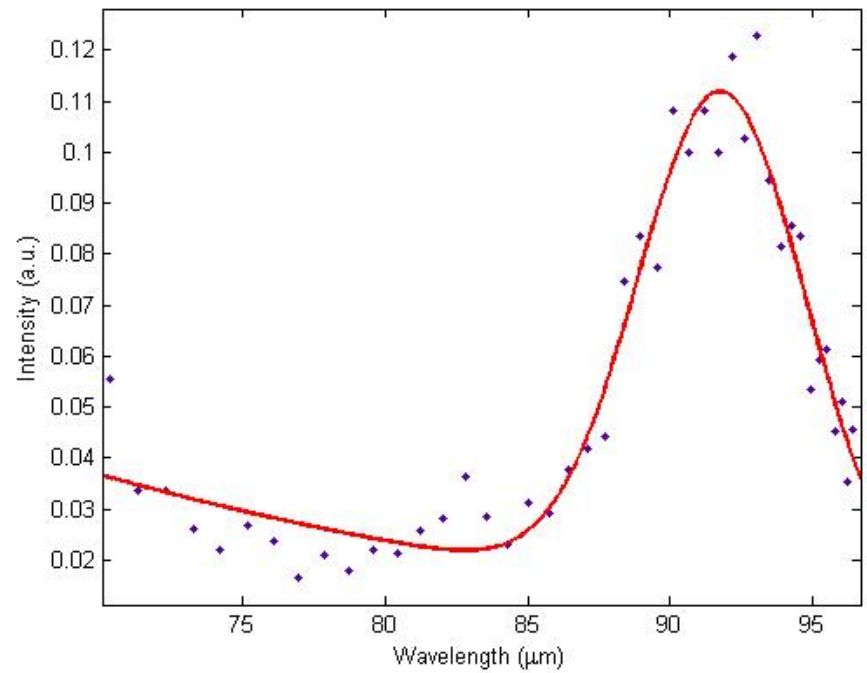
Peak at 54.4µm ± 1.3µm ± 0.5µm (9%)
FWHM: 11.8%±1.2% (11.1% expected)

Results

Wavelength shift



Undulator at 85µm



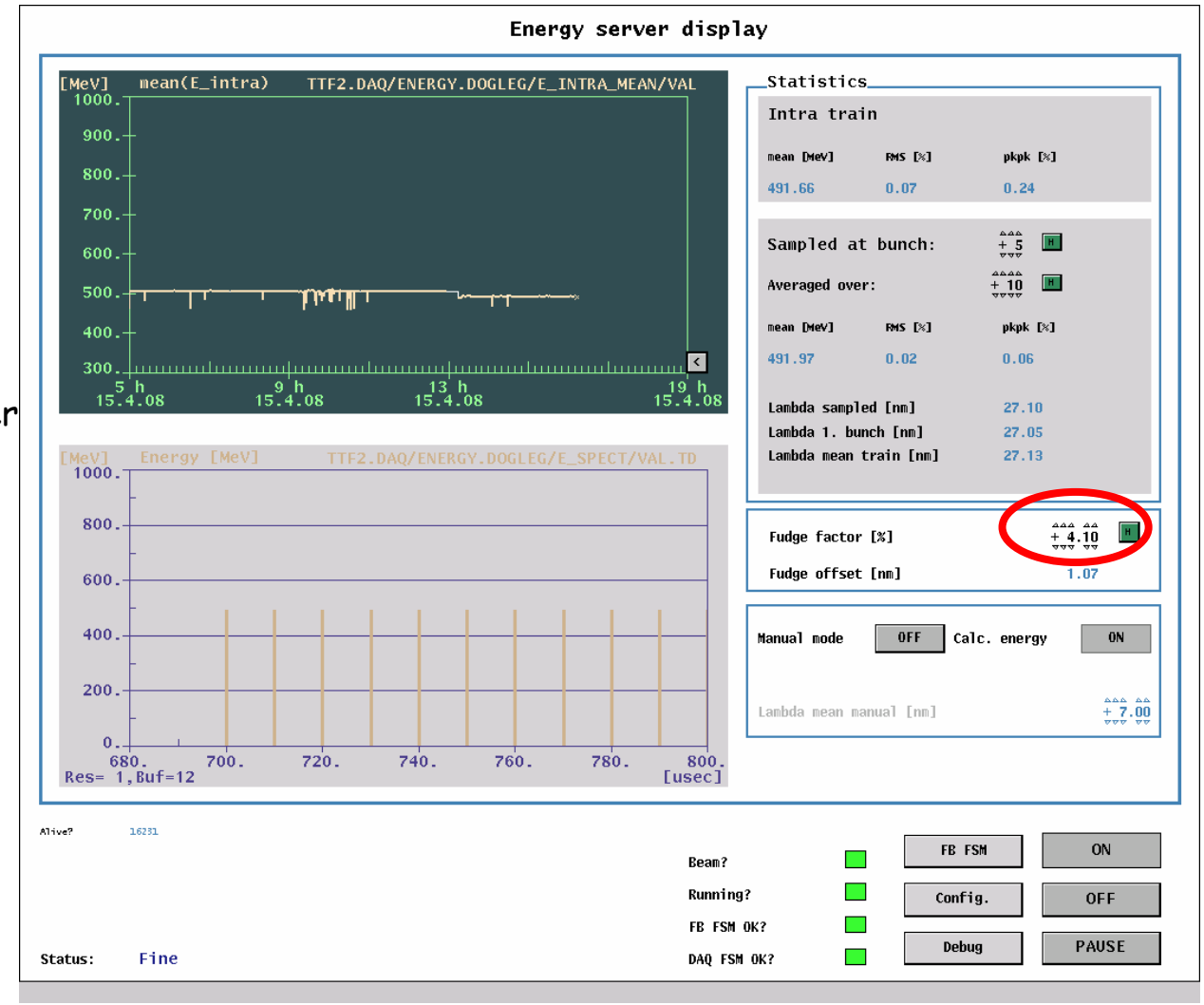
Peak at 91.8µm ± 0.4µm±0.7µm (8%)
FWHM: 10%±1.4%

Results

Wavelength shift

Undulator server calculates the wavelength with energy from energy server

Energy server calculates the center-of-mass energy!

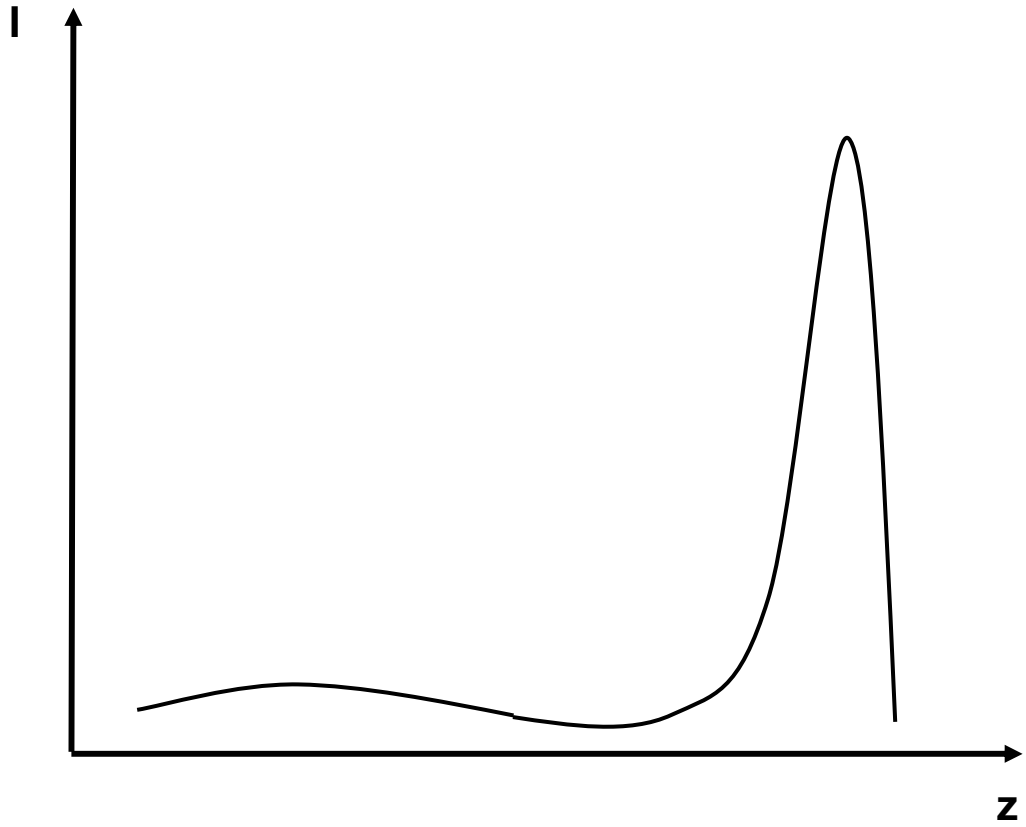


Results

Wavelength shift

Bunch does not lase
at center-of-mass
energy!

=> Same in IR undulator??



Results

Wavelength shift

- Influence of Quadrupoles?
- Influence of Sextupoles?

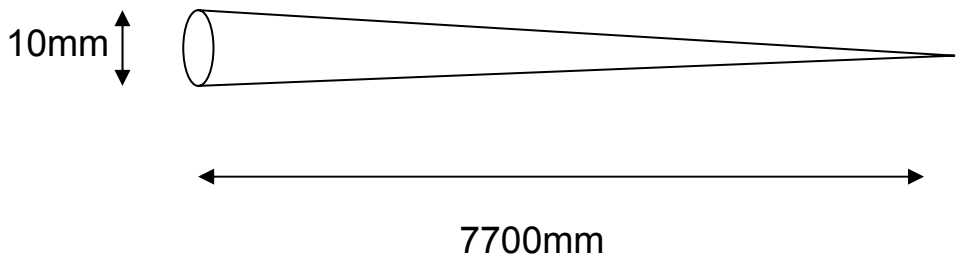
} Change the wavelength without changing the CMS energy

Lasing region does not have to be the same as the bunch part which emits infrared radiation!

Results

Wavelength shift

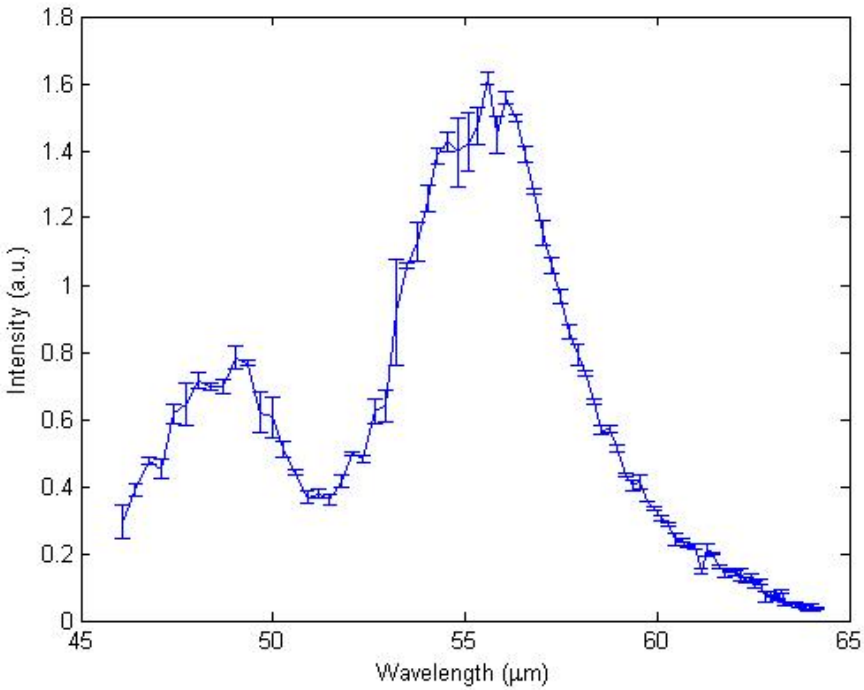
Influence of hole in first mirror?



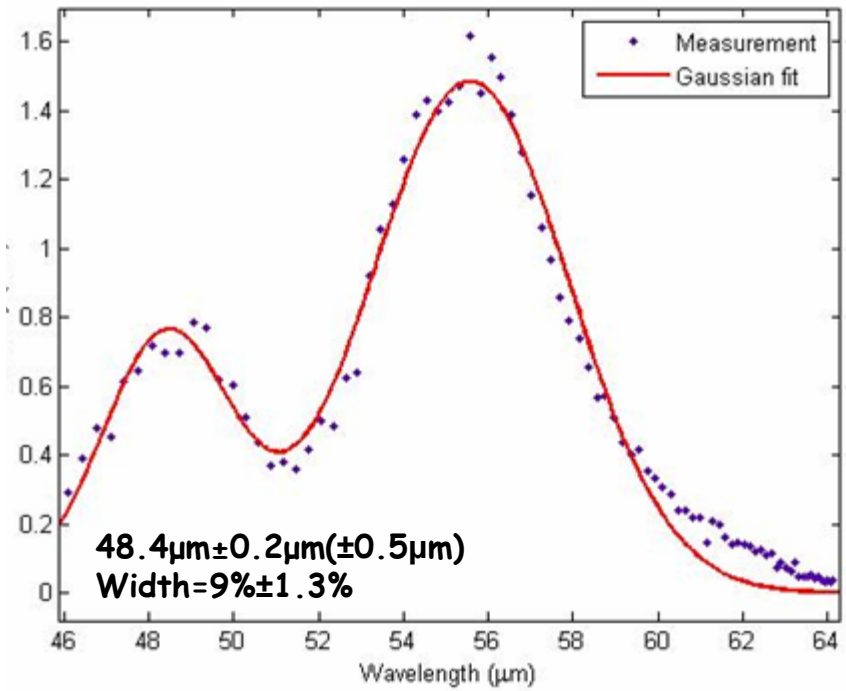
→ Varies between 0.2% for max. K (K=44) and moderate energy (500 MeV) and 2.5% for small K (K=10) and high energy (1 GeV)

Results

Multiple peak spectra



55.6µm±0.1µm(±0.5µm), w=10±1.3%



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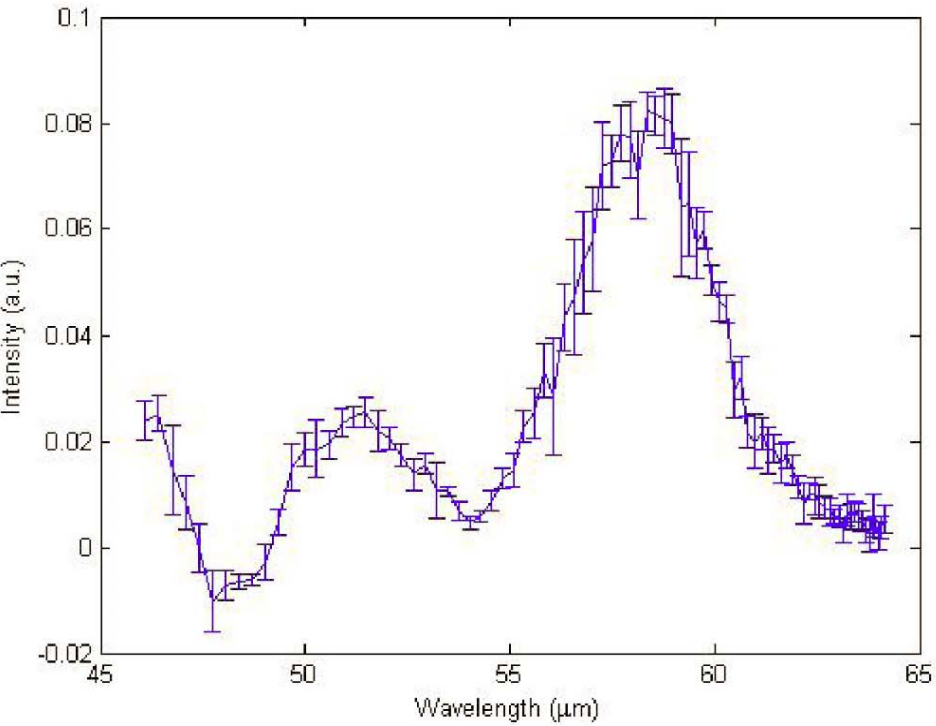
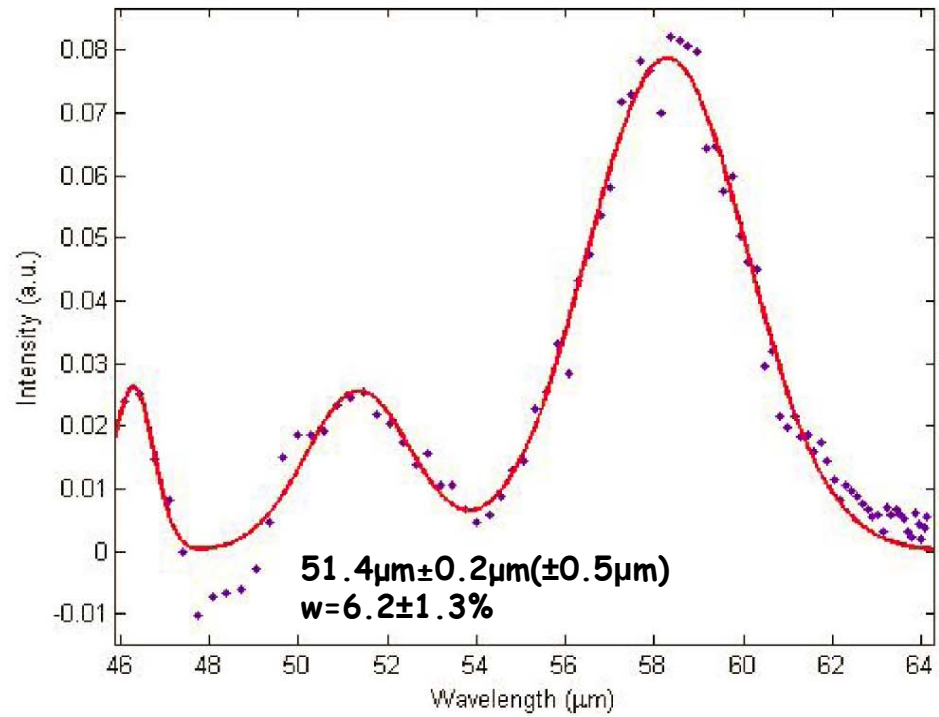


Undulator at 52.5µm

58.3µm±0.1µm(±0.5µm)
w=7.2%±1.3%



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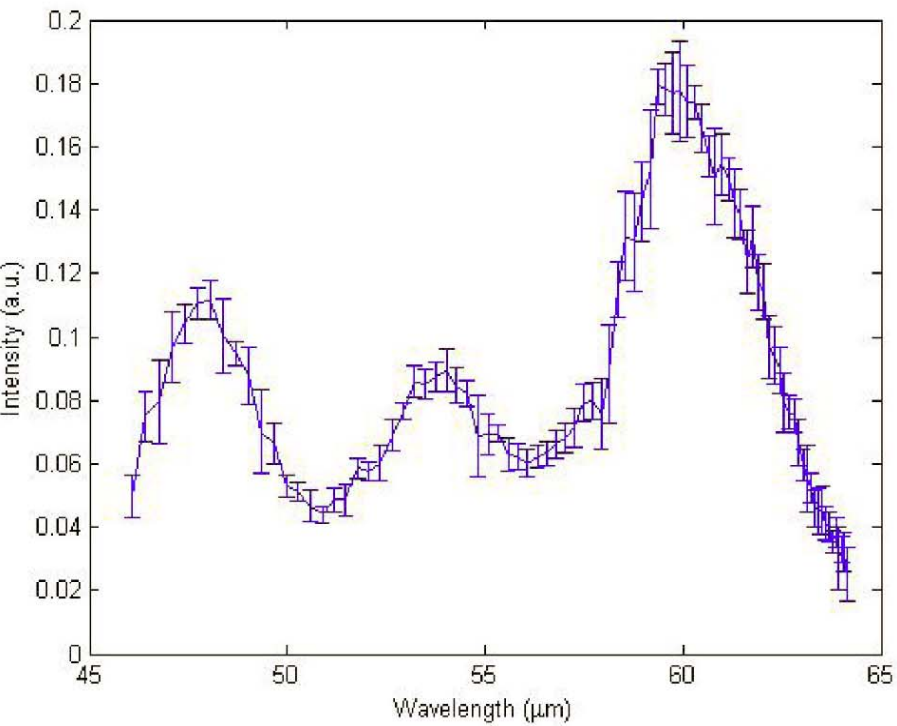
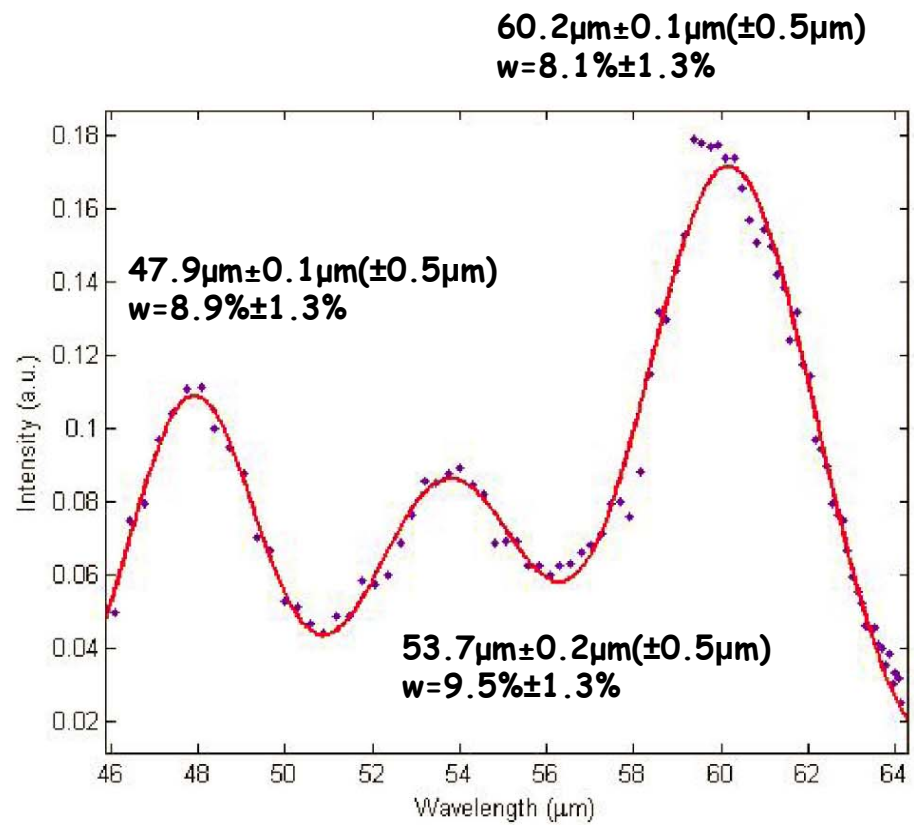
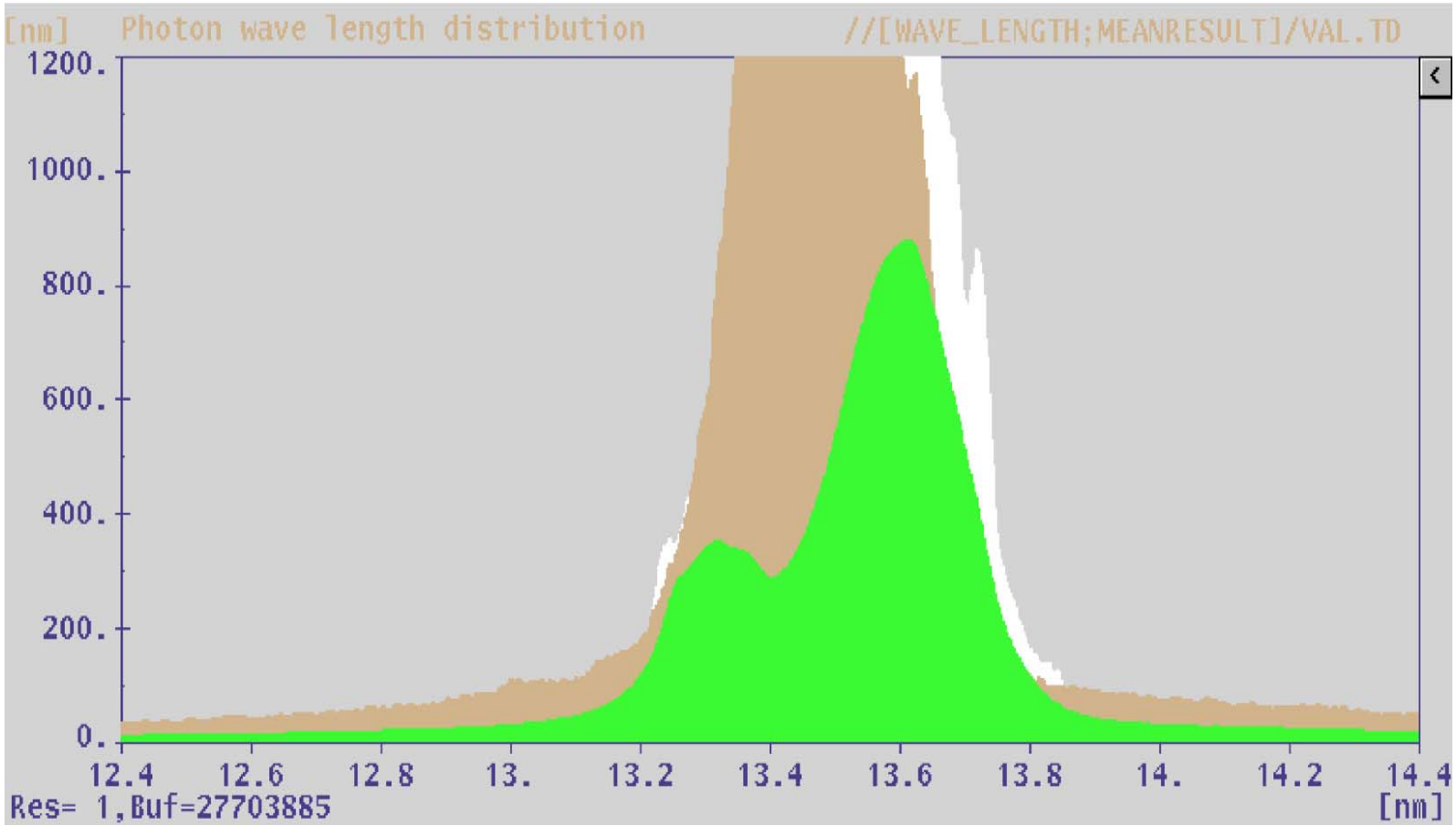


Undulator at 55µm



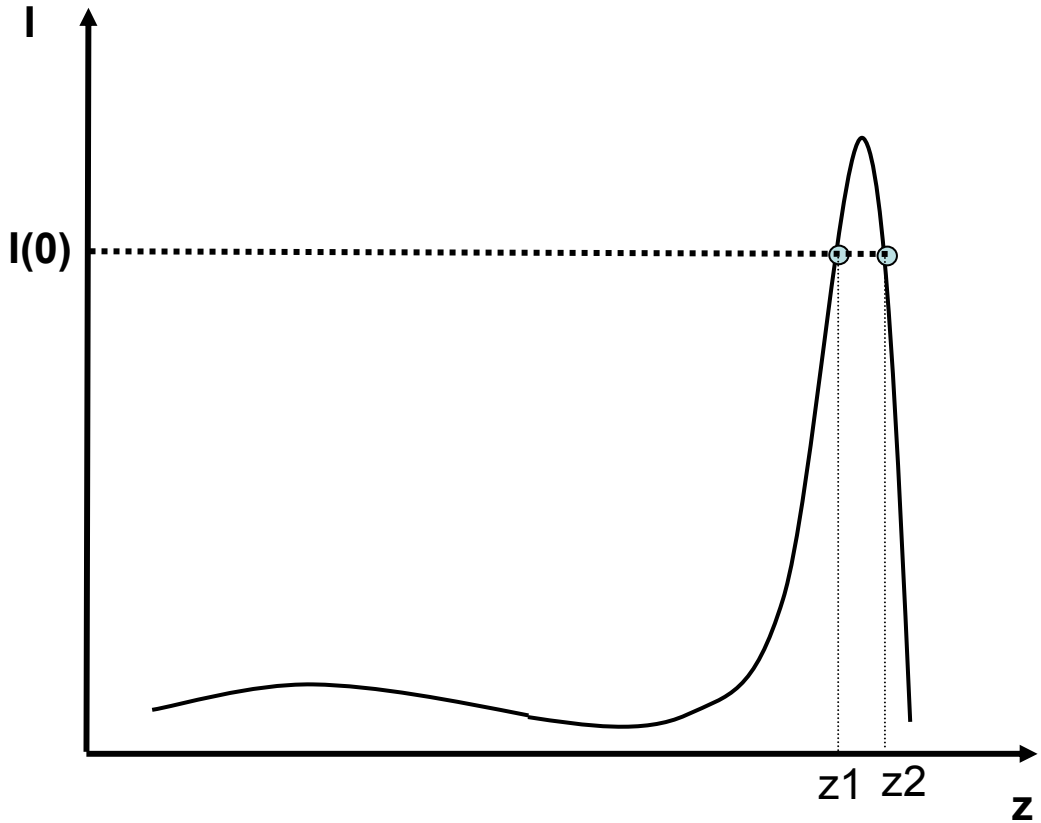
Results

Multiple peak spectra



Results

Multiple peak spectra



Results

Multiple peak spectra

- But: Spectrum not dependend on transverse effects => emittance not important
- More than one peak is observed
- Difference of energies 5% => limit of dogleg reached

Results

Multiple peak spectra

- But: Spectrum not dependend on transverse effects => emittance not important
- More than one peak is observed
- Difference of energies 5% => limit of dogleg reached

Maybe…

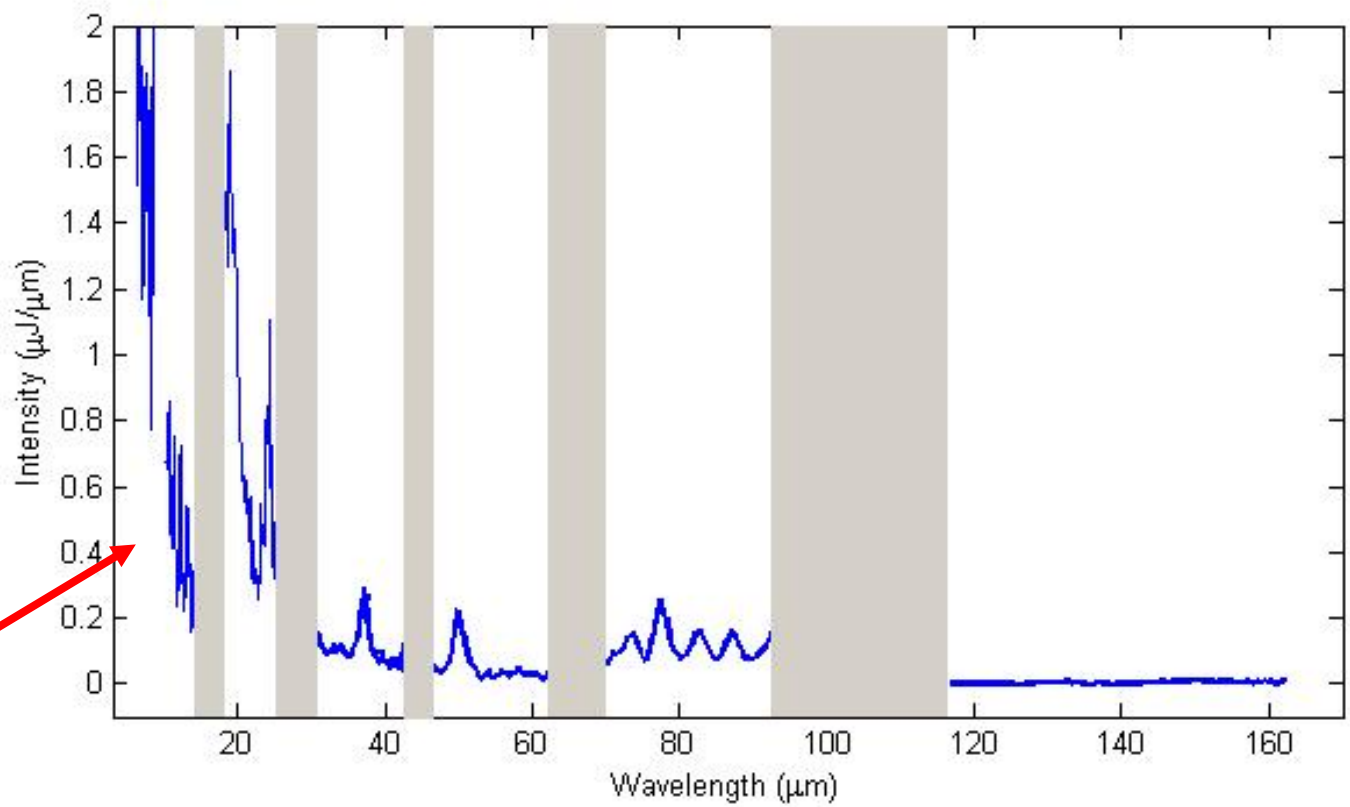
- Energy jump in an acceleration module -> max. jump about 6% (dogleg)
- Klystron of ACC 4/5/6 was brought back to operation before the shifts
- An effect of SASE? Lasing? Instrument?

Results

Full scan 140µm

Corrections:

Detector response
Grating efficiency
Diamond window
Polarizer
Resolution function



Huge background

Results

Full scan 1

Corrections:

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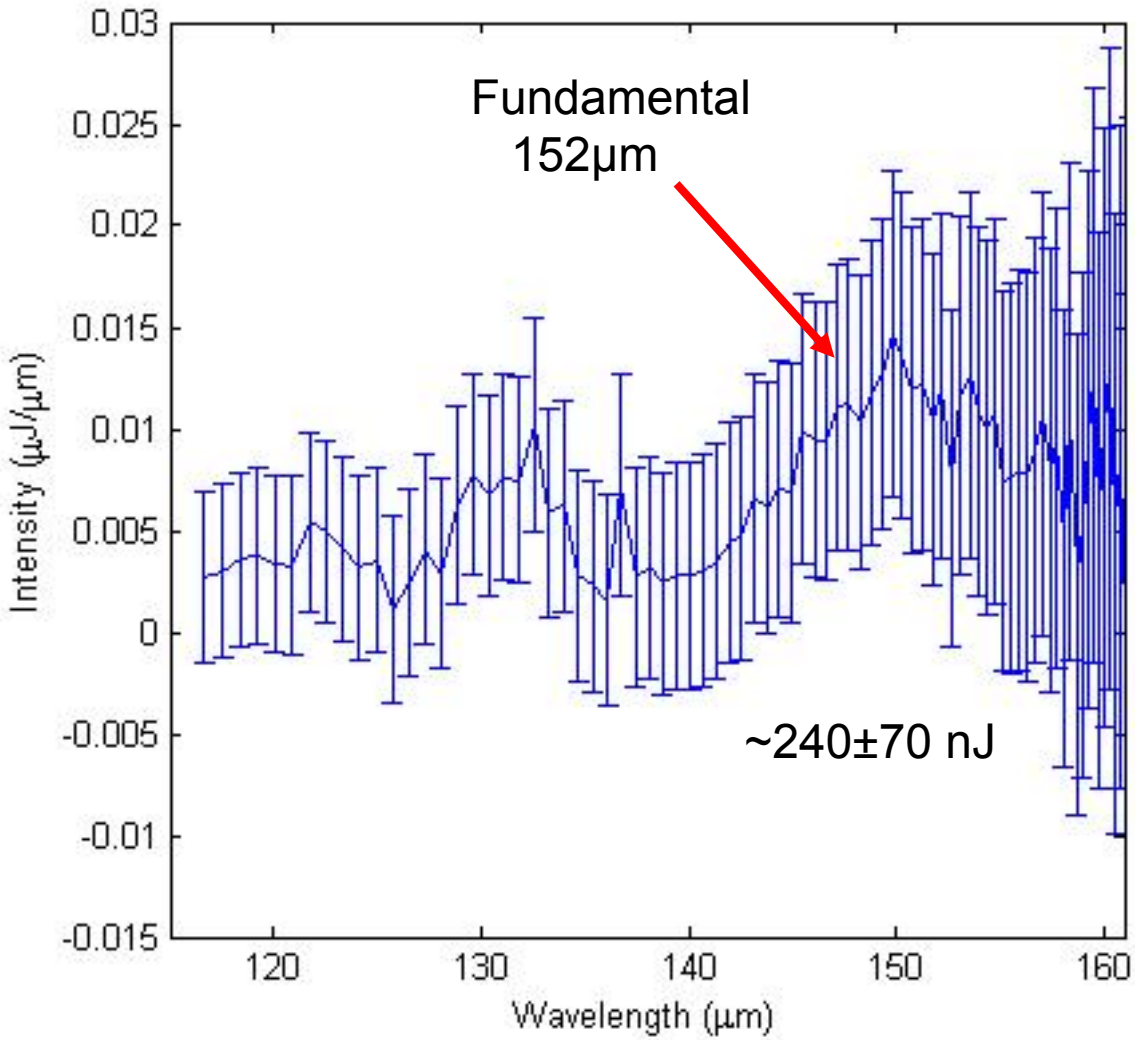
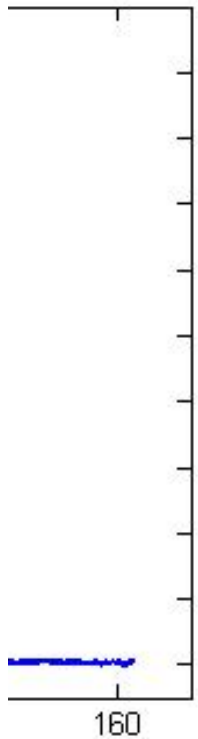
Huge backgro





Results

Full scan 14

Corrections:

Detector respons
Grating efficiency
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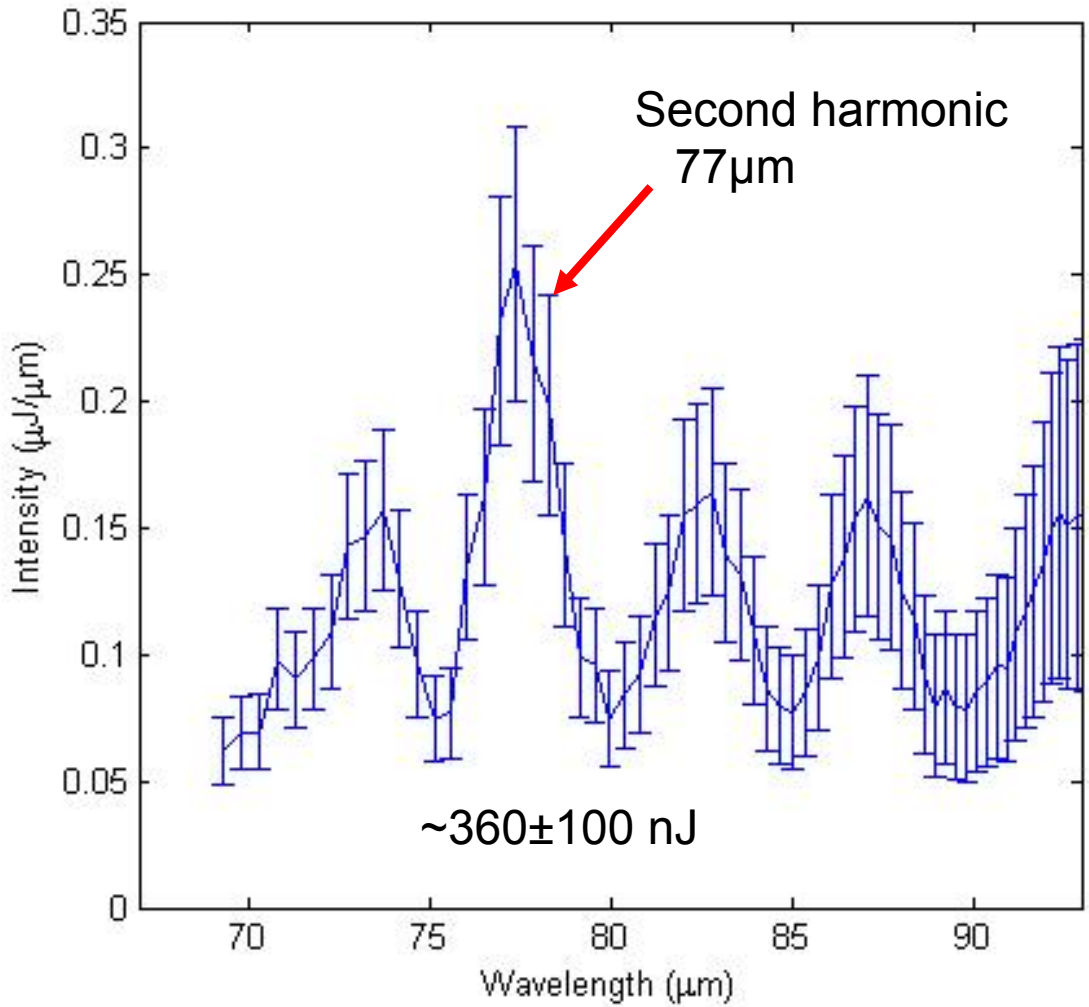
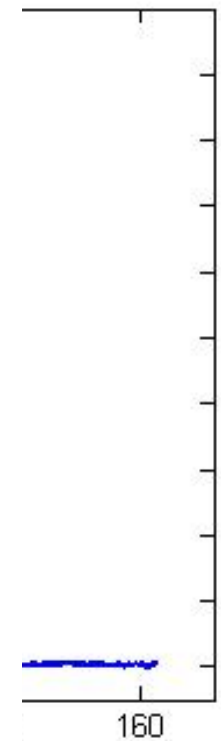
Resolution functic

Huge backgrou





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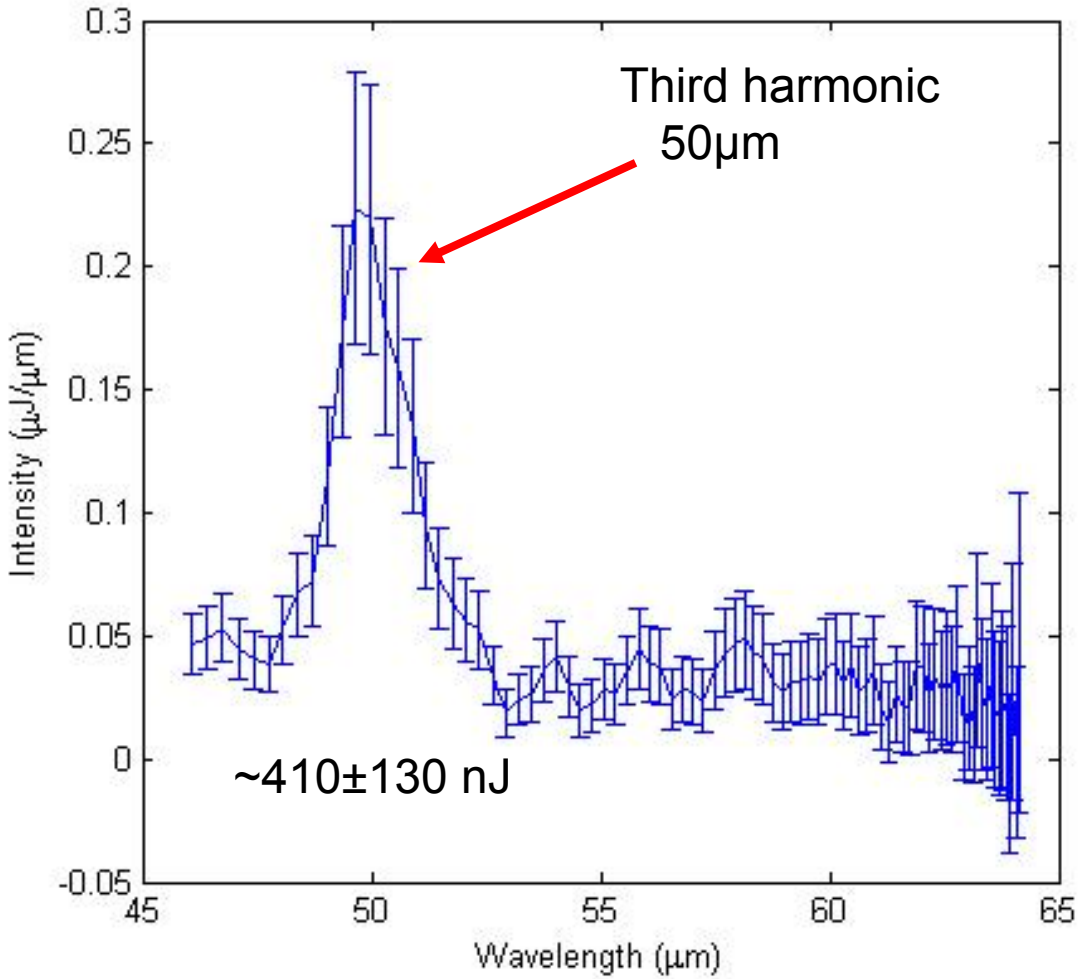
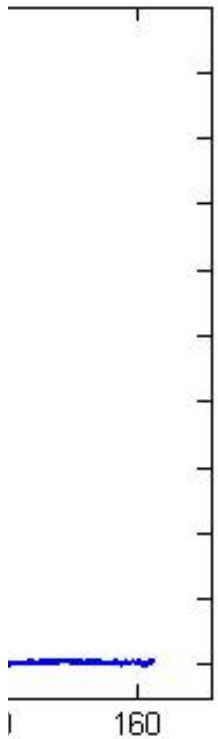
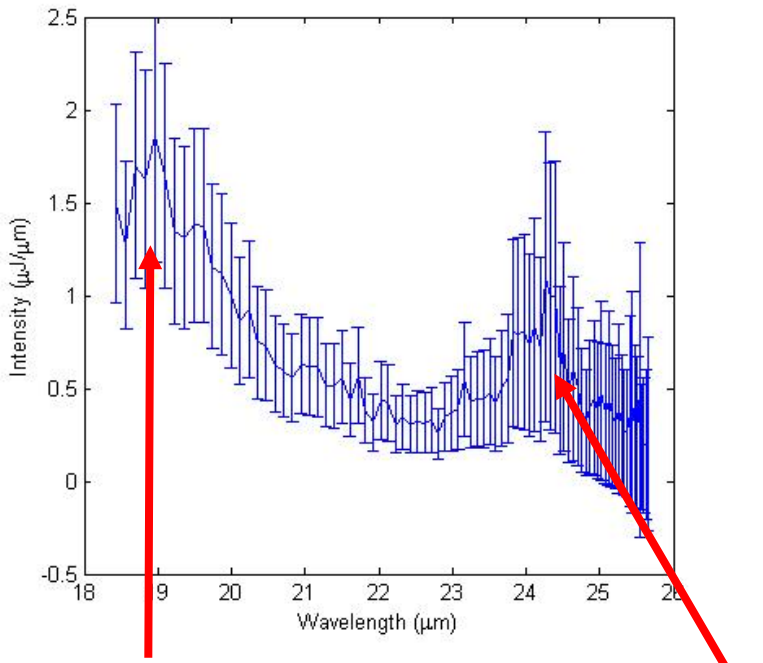
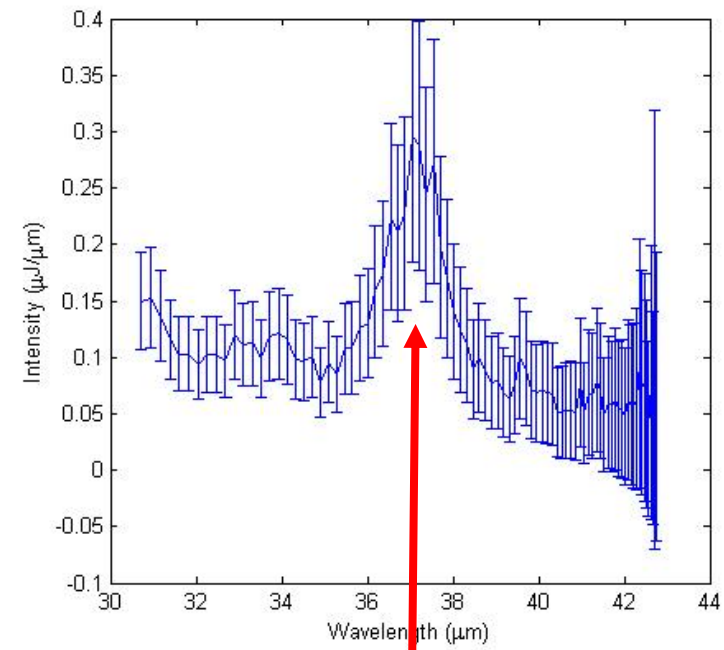
Huge backgrour





Results





19±0.4±0.3µm
Shift of ~9%: 8. harmonic
Shift of ~22%: 9. harmonic
Shift of ~-5%: 7. harmonic

24.2±0.1±0.3µm
Shift of ~4%: 6. harmonic
Shift of ~-14%: 5. harmonic
Shift of ~21%: 7. harmonic

37.2±0.1±0.3µm
Shift of ~6.3%: 4. harmonic
Shift of ~33%: 5. harmonic

1. 140, 2. 70, 3. 46.7, 4. 35, 5. 28, 6. 23.3, 7. 20, 8. 17.5, 9. 15.55

Results

Full scan 140µm

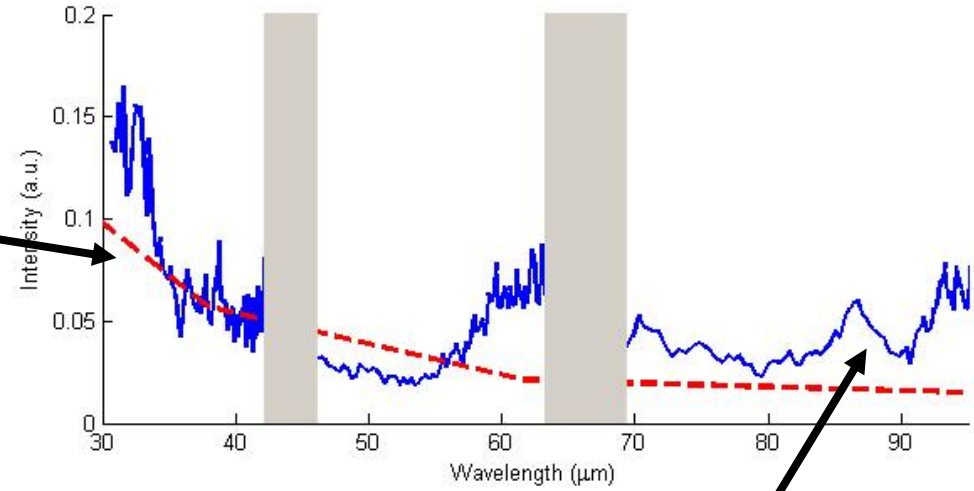
- 2nd harmonic due to electron path? Edge effects?
- Odd harmonics higher than 5 (5 not visible due to grating gap) suppressed by the form factor?
- Different shift for higher harmonics? (against short wl-measurements)
- Why is the fundamental that weak -> beamline transmission?

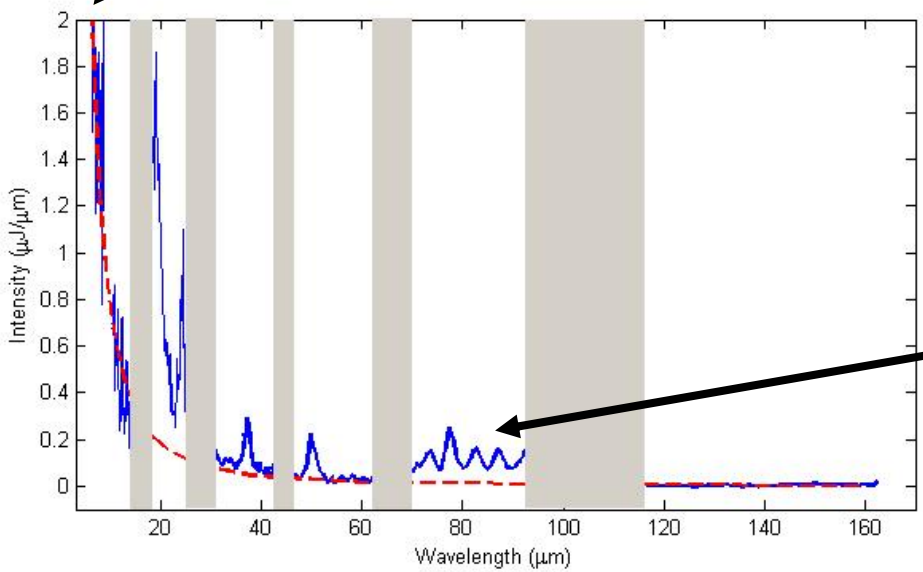
- Origin of the background?

Results

Background

Simulated single-particle spectrum of dump magnet





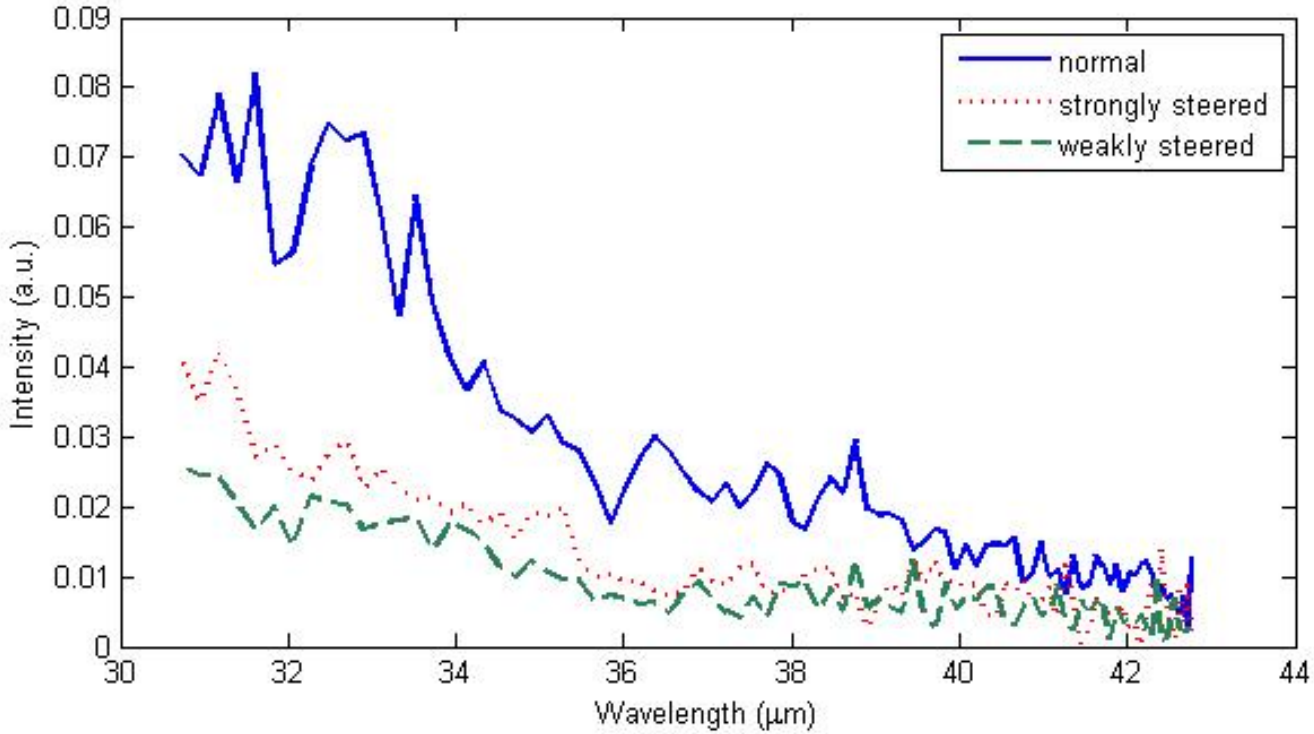
Measured spectrum

Results

Background

Method:

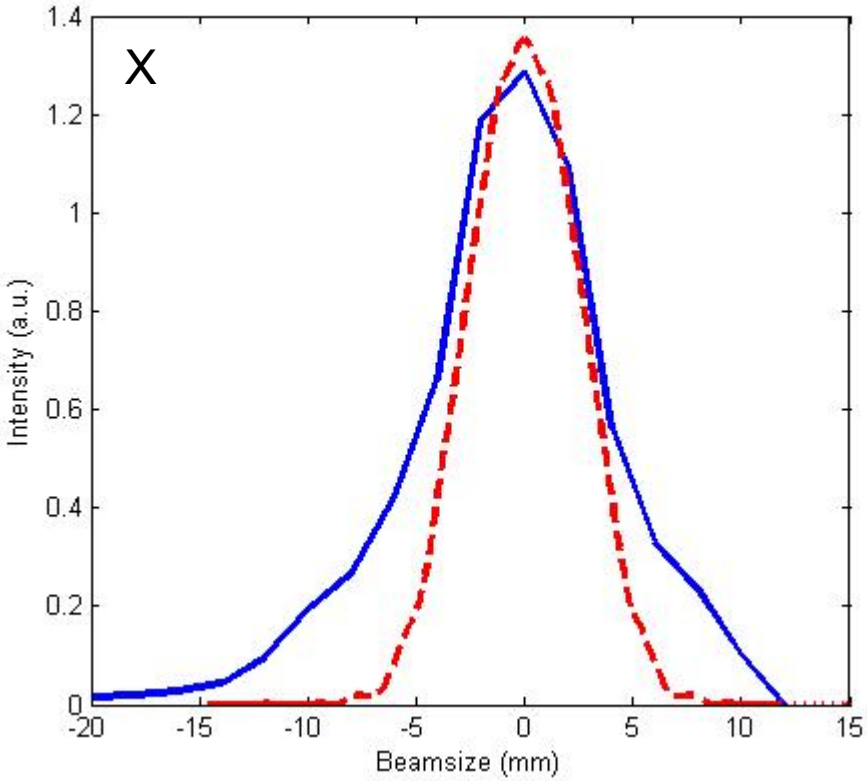
Beam dumped into
Beam pipe.

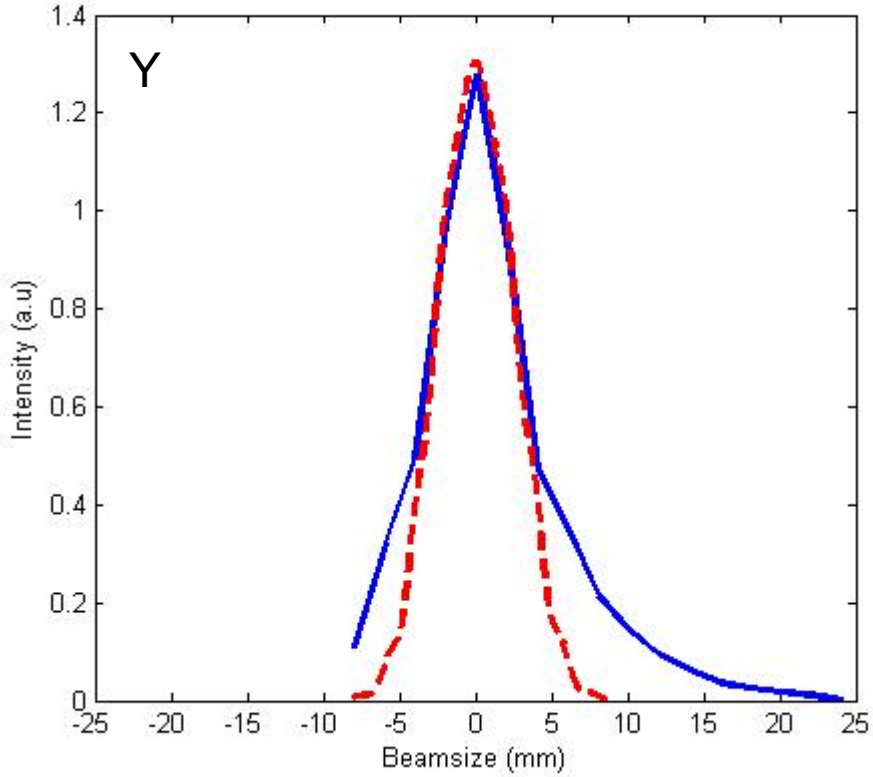


Results

Beamprofile

At the position of the polarizer





Conclusion

Conclusion

- Wavelength is shifted towards longer wavelengths (varies from 8% to 12%)
- Machine status has an effect on spectra of IR undulator:
  - additional peaks appear
  - wavelength shift varies
- We see odd and even harmonics and a weak fundamental for 150µm
- Huge background at short wavelengths from dump magnet
- Beamprofile differ slightly from simulations
- Not shown: Spectrum not sensitive to correction coil settings and slight orbit misalignment

Outlook

Outlook

- For the wavelength shift, investigations into the energy server are planed
- Multiple peak structure needs further investigations –
  first a reproduction has to be achieved
- Vacuum setup will be developed for DP3
- Setup at DP2 will be installed during next shut down

Thank you!

Bernhard Schmidt
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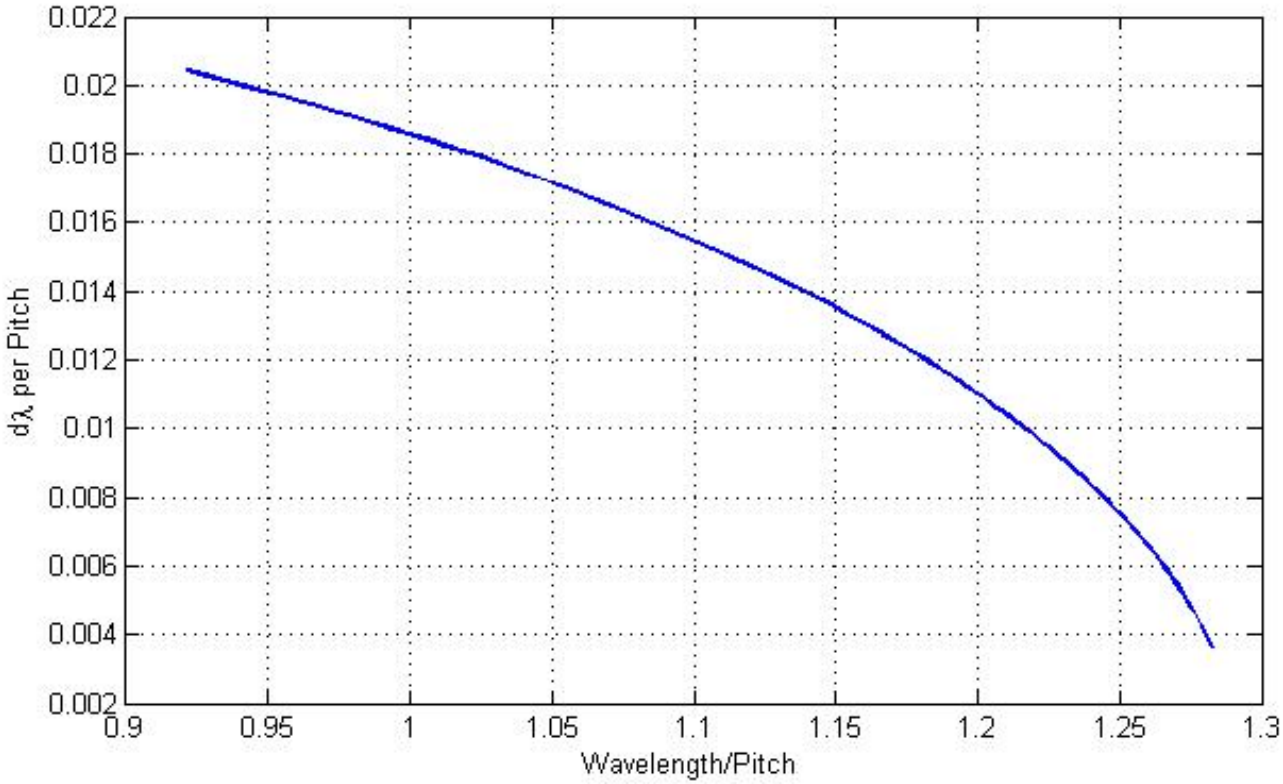
Christopher Behrens
Hossein Delsim-Hashemi
Otto Peters
Mathias Böttcher
Bernd Beyer
Peter Danielak
Ulrike Frühling
Michael Gensch
Matthias Hoffmann

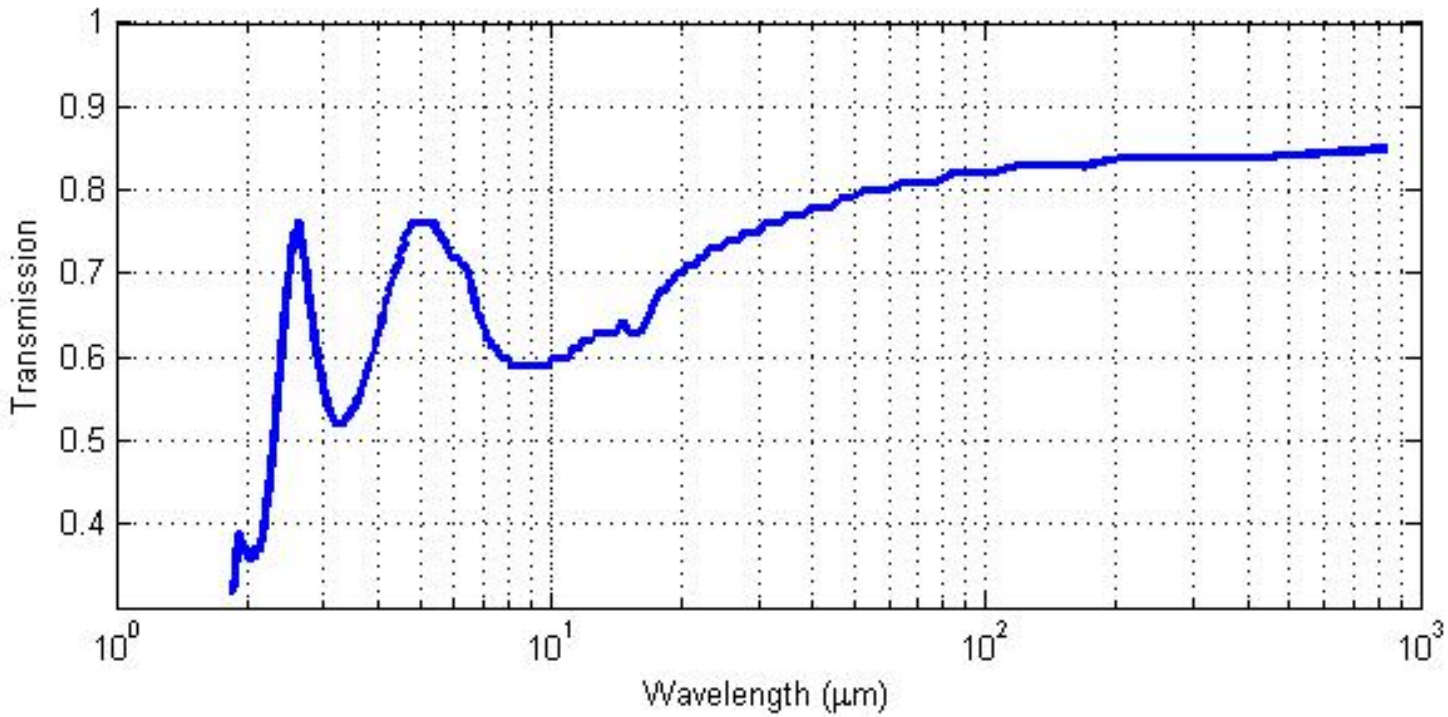
Oliver Grimm

Resolution function



Zurück

Transmission Polarizer

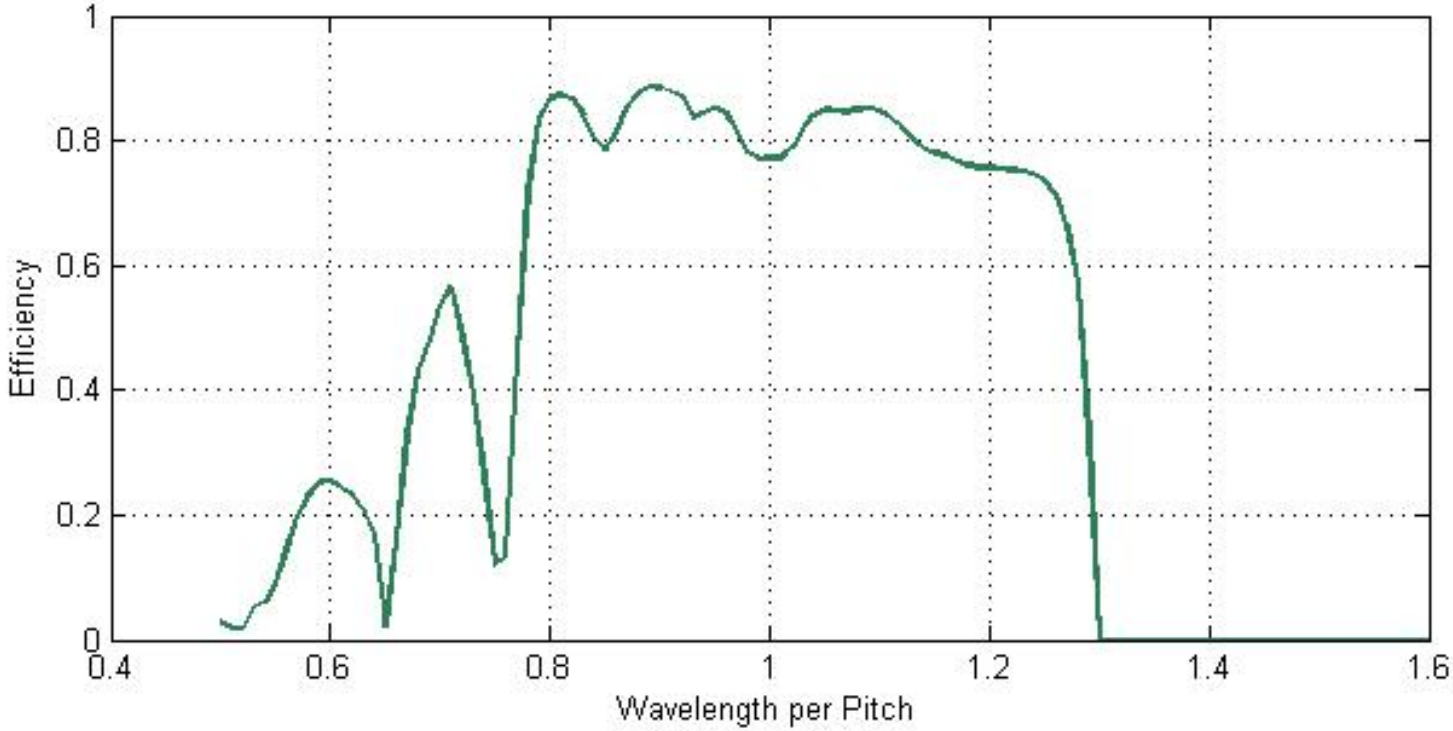


Zurück

Diamond transmission

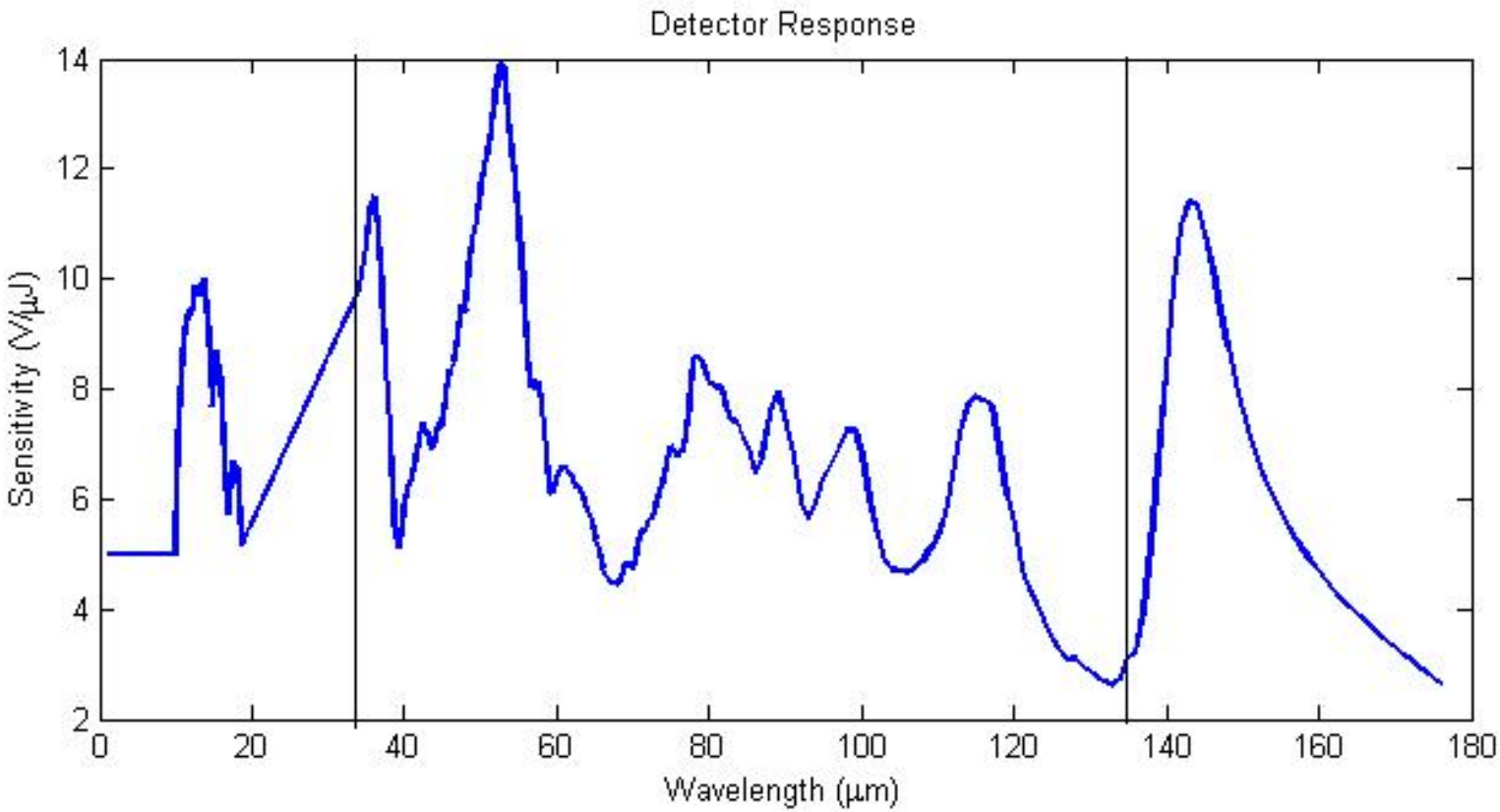
Zurück

Grating efficiency



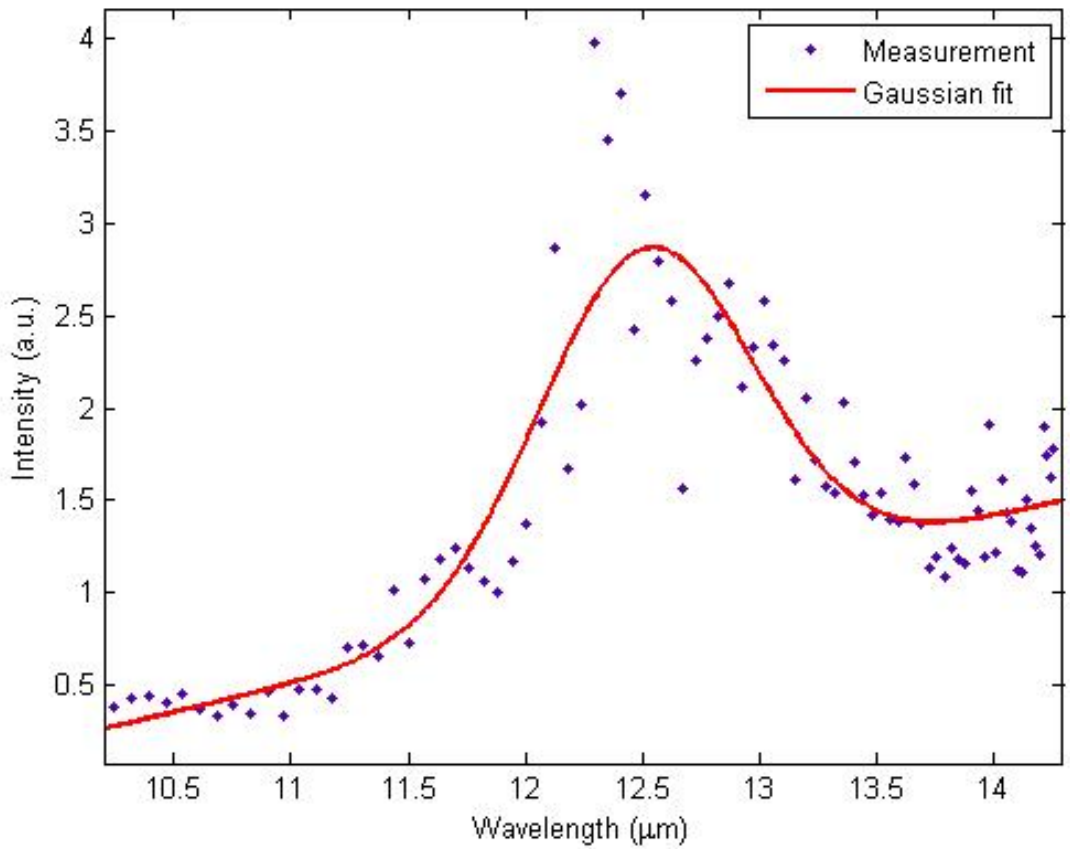
Zurück

Detector response



Zurück

Spectrum at 11.5µm



12.5±0.1±0.1
~9%

Zurück