Microbunching Studies using IR Spectroscopy and TDS

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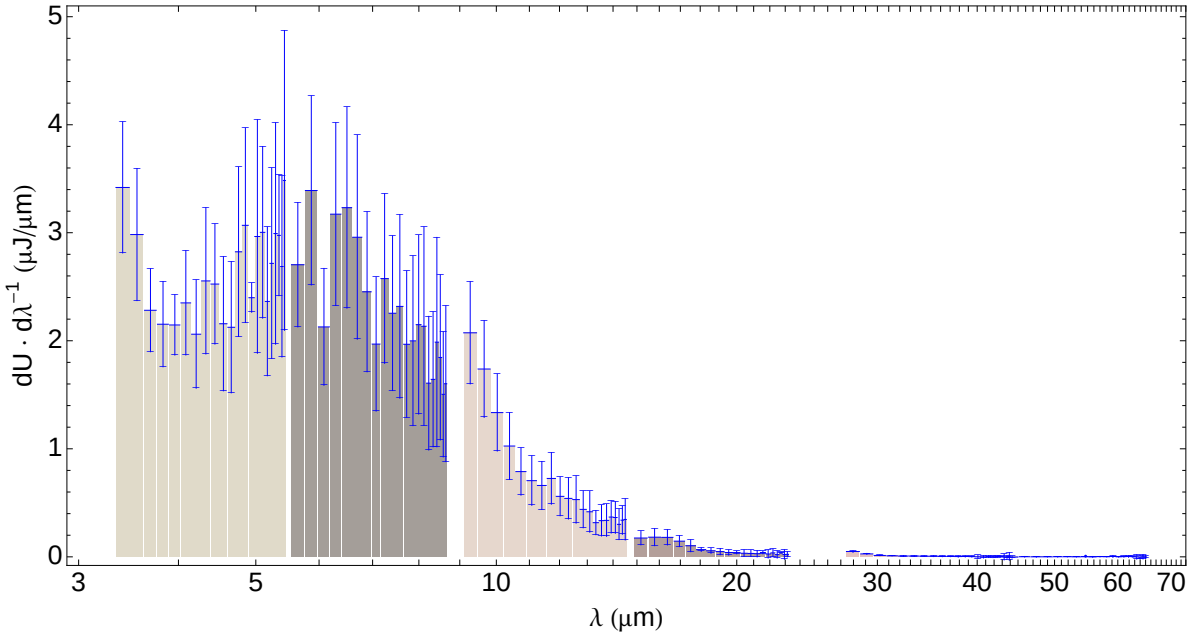
Overview

1. Motivation
2. Instrumentation
3. Measurements
4. Conclusion

IR CTR



$E_0 = 700\,\mathrm{MeV}$, $Q = 0.5\,\mathrm{nC}$

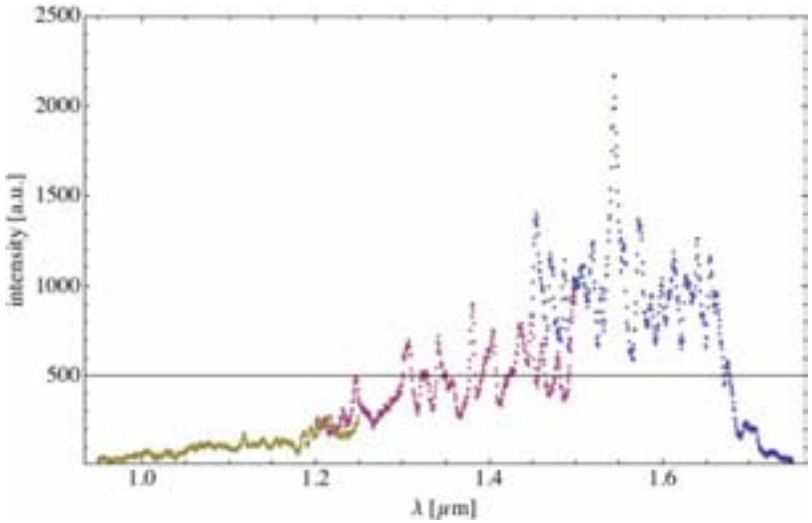
Oncrest spectra:

- coherent radiation in spectral range of $\lambda = [3.3, 20]\ \mu\mathrm{m}$
- intensity level in same order as from compressed bunches
- >1% of the electrons inside the bunch radiate coherently
- strong fluctuations of the oncrest spectrum

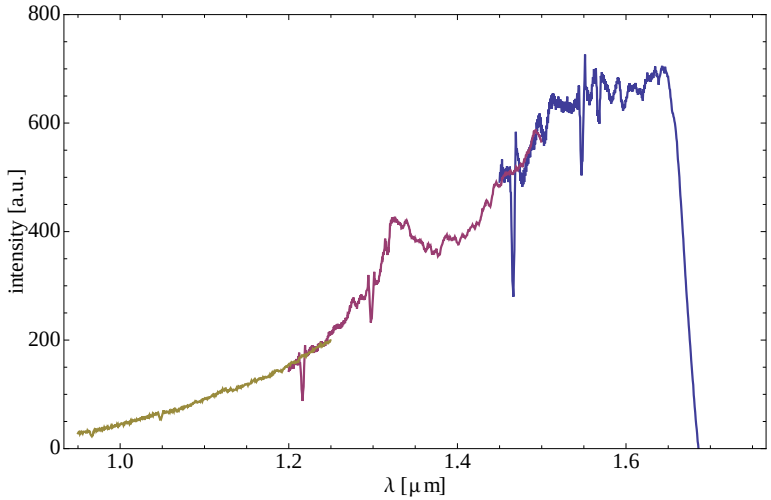
$\longrightarrow$ nearly always present!

NIR CTR

Single shot (SASE conditions)



Average



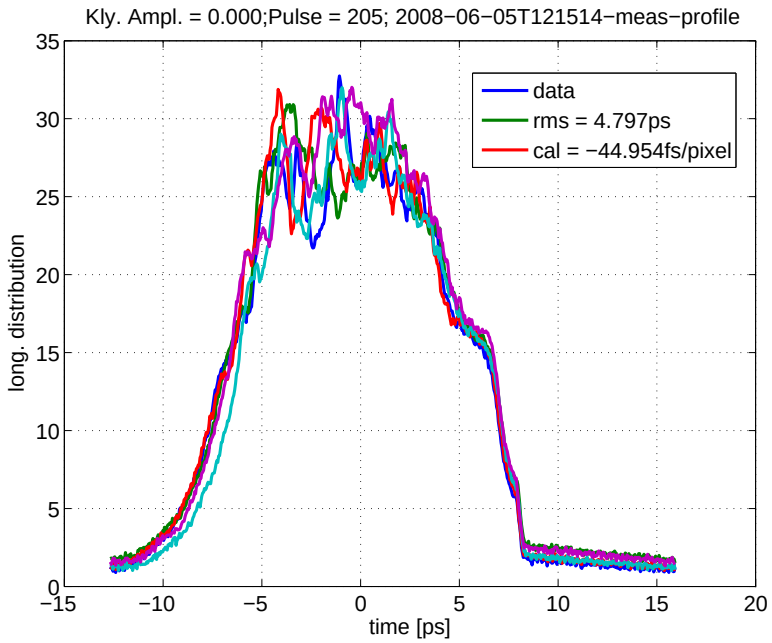
InGaAs spectrometer:

- extension of IR spectrum ($\lambda = [0.9, 1.7]\ \mu\mathrm{m}$)
- average intensity decreases down to optical wavelengths
- single shot spectrum consists of extreme narrow and highly fluctuating spikes

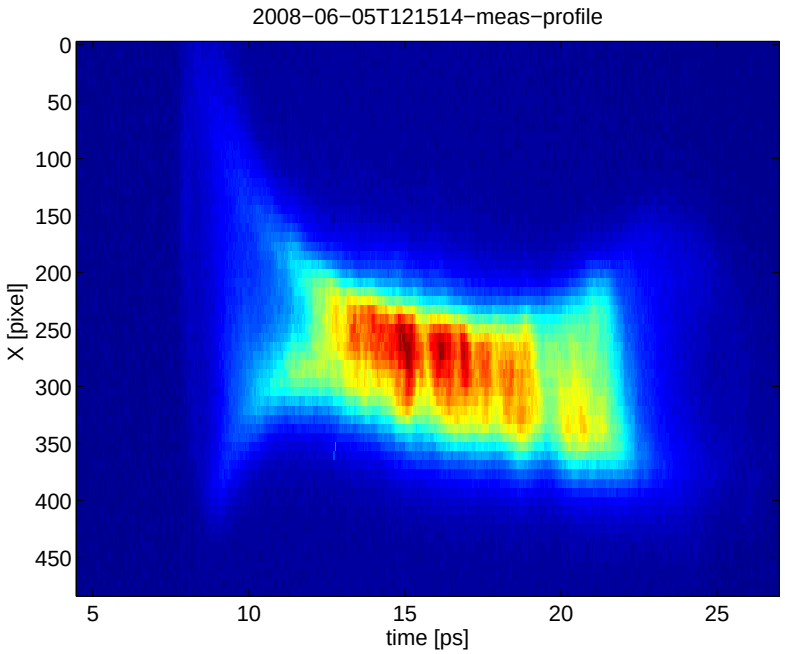
→ OTR measurements should confirm coherent signals!

COTR (?)

Observation in June ’08 showed first evidence of coherent signals in the optical regime



courtesy H. Schlarb



Questions:

- reproduceable ?
- special FLASH setting ?
- location (longitudinal) in electron bunch ?

Microbunching

Substructure inside the electron bunch, which is not related through the correleted energy spread and can radiates coherently via CTR, CRD or CSR.

Simple LSC model:

→ transformation from energy to density modulation is given by R56

→ substructure length should be varied by changing R56

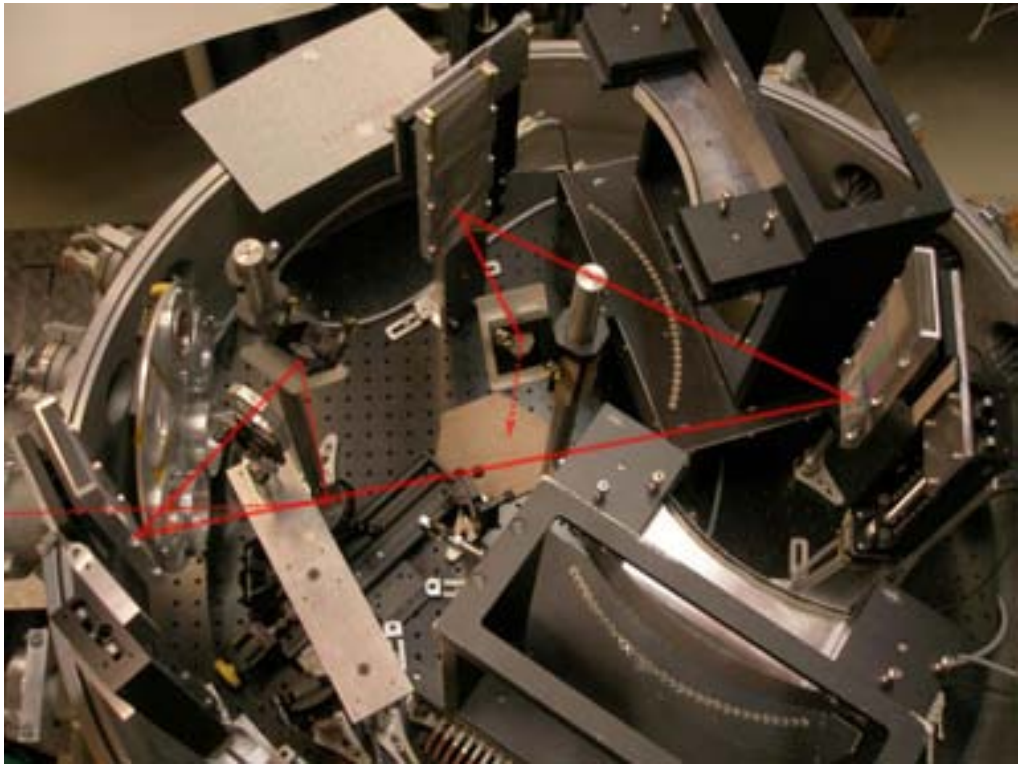
→ spectrum shape and intensity should be influenced

Note:

both R56 are mandatory for detectable IR radiation

see FLASH talk (08-04-08)

IR spectrometer



see H. Delsim-Hashemi FLASH talk (08-03-04)

Characteristics:

- staging of 2 dispersive reflective gratings
- radiation detection by 60 pyroelectric senors (only coherent signals)
- single shot capability in 3 wavelength ranges
  i. 3.3 μm - 9 μm
  ii. 9 μm - 22 μm
  iii. 25 μm - 65 μm
- CTR off-axis screen served by TDS kicker
- port about 4 m upstream of TDS screen
- beam transport with THz beamline

TDS

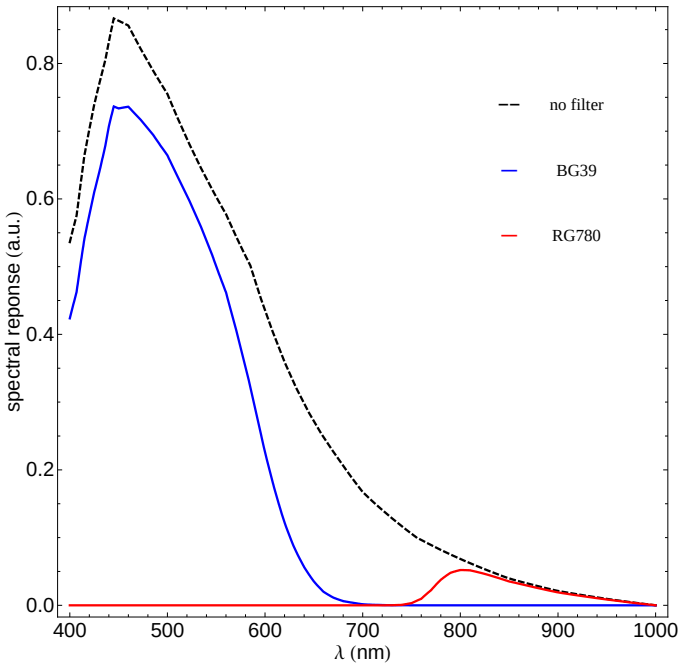
TDS port + filter wheel + camera system

Port characteristic:

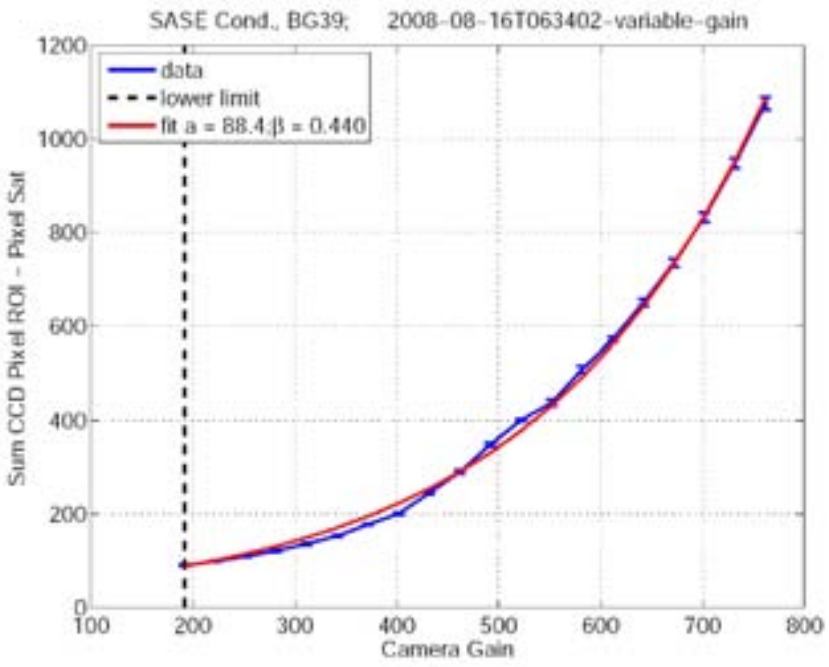
- deflection of single bunch by fast TDS kicker on screen
- imaging radiation by Basler monochrome camera
- 2 color filters (Schott glas BG39 / RG780) in filter wheel to resolve spectral content

TDS

Spectral response of camera × incoherent OTR intensity



Intensity variation in respect to camera gain



courtesy H. Schlarb

Plan

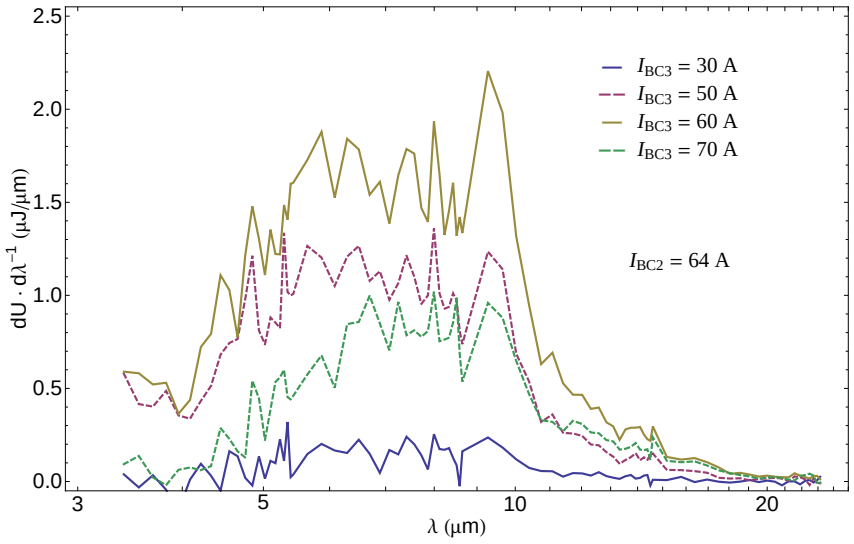
FLASH settings:

- $E_0 = 780\,\mathrm{MeV}$
- $\phi_{\mathrm{ACC1}} = \phi_{\mathrm{ACC23}} = \phi_{\mathrm{ACC456}} = 0^\circ$
- $Q = 0.75\,\mathrm{nC}$ ($\pm$ 1.3%)

Procedure:

0. set BC currents
1. readjust phases
2. focus on TDS screen
3. take TDS images
4. take IR spectra

IR spectrometer I



I_{BC3} - variation:

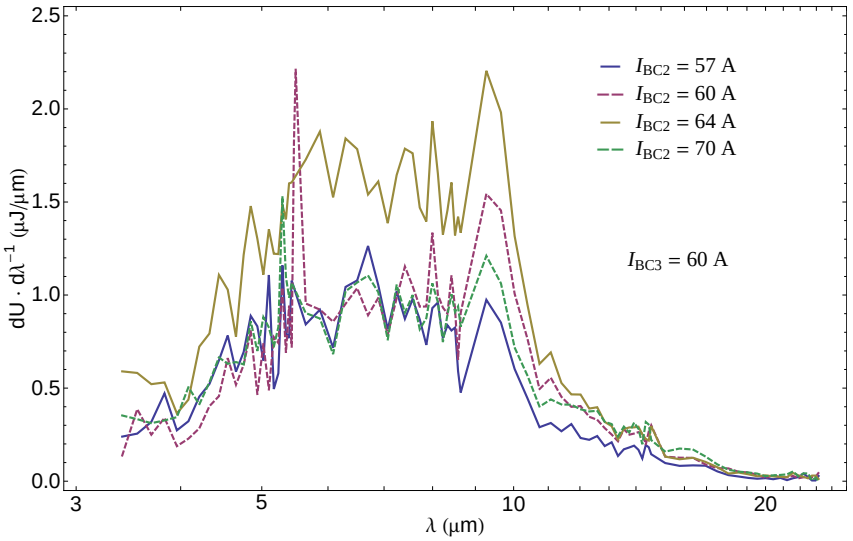
→ increase of spectral intensity with R56

→ no shift of center wavelength

I_{BC2} - variation:

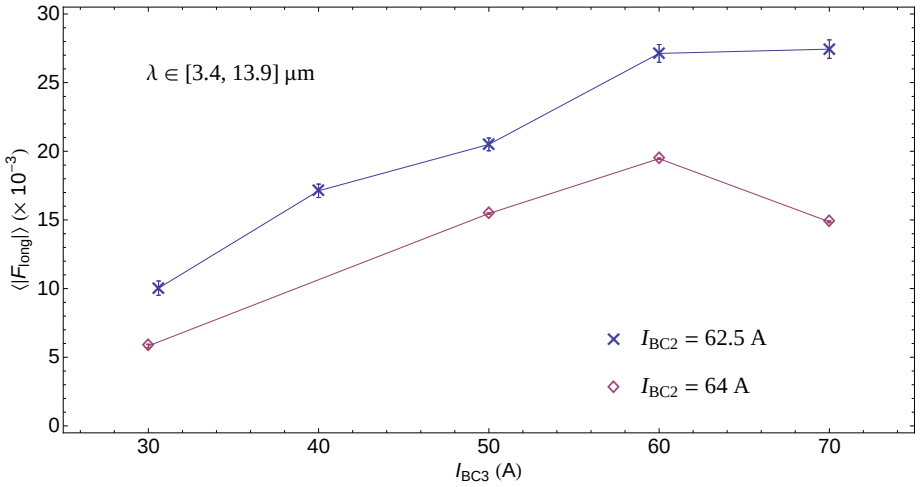
→ no significant intensity variation except for I_{BC2} =64 A

→ no drift of center wavelength

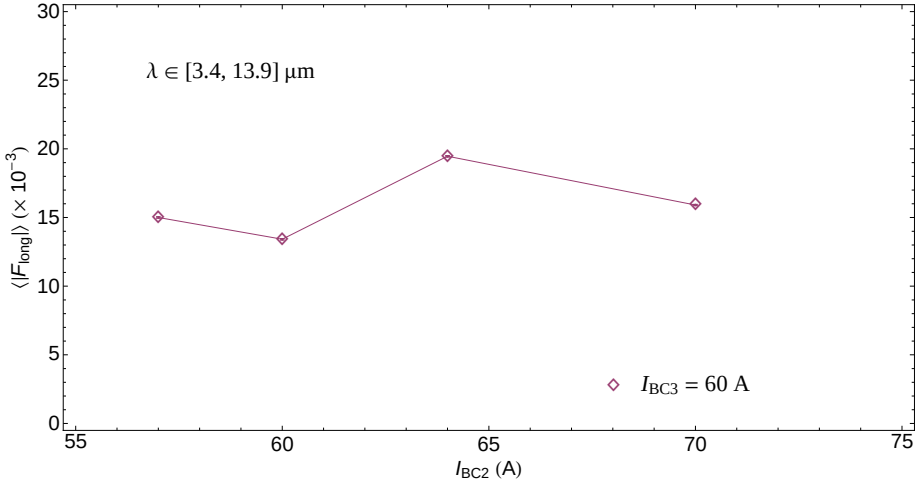


IR spectrometer II

I_{BC3} - variation:



I_{BC2} - variation:



Formfactor:

$$|F|^2 = N^{-2} \cdot \left(\frac{dU}{d\lambda}\bigg|_{\text{incoh.}} \right)^{-1} \cdot \frac{dU}{d\lambda}$$

$\longrightarrow$ averaging F over $\lambda = [3.4, 13.9]\ \mu$m

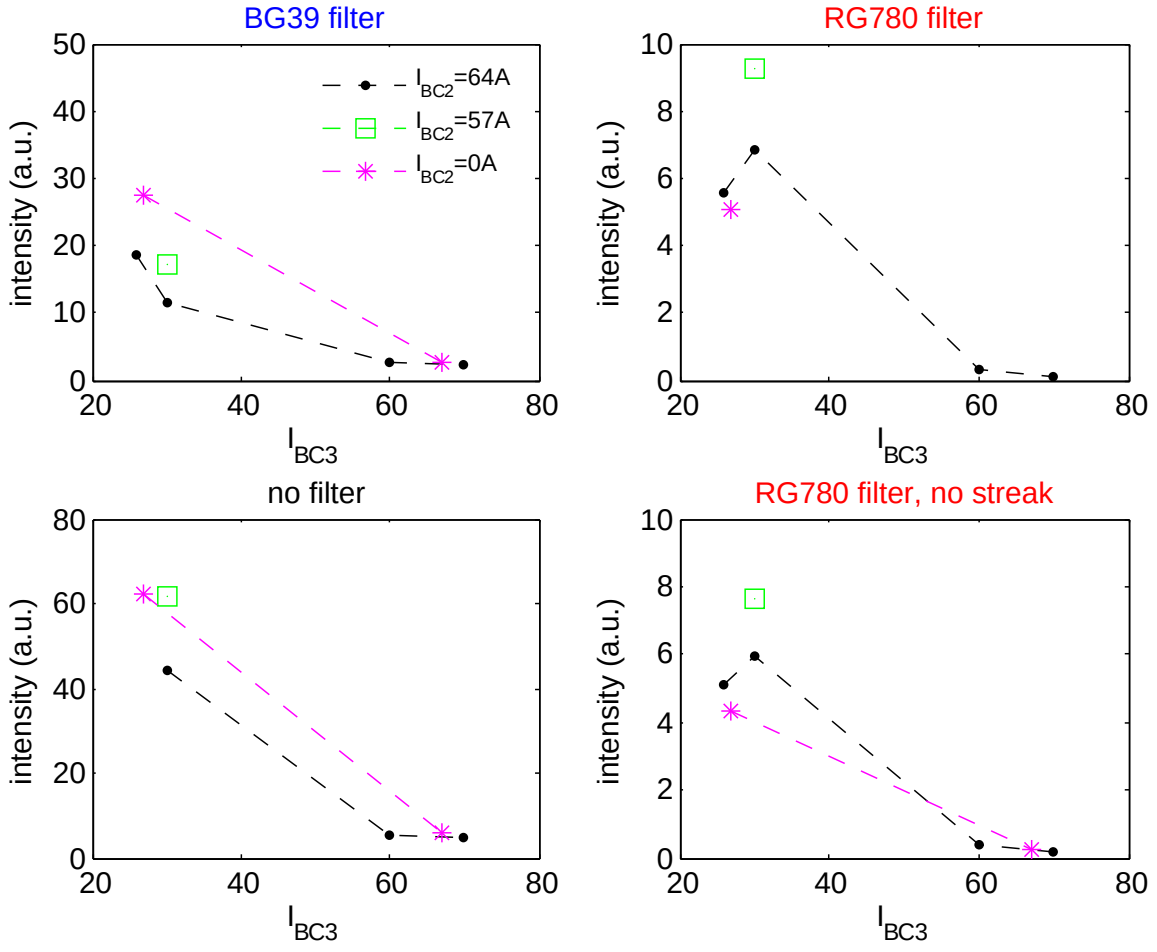
Results:

- increasing BC3 current $< F >$ increases up to saturation (factor of 4!)
- increasing BC2 current $< F >$ no significant effect

OTR images I

Videos

OTR images II



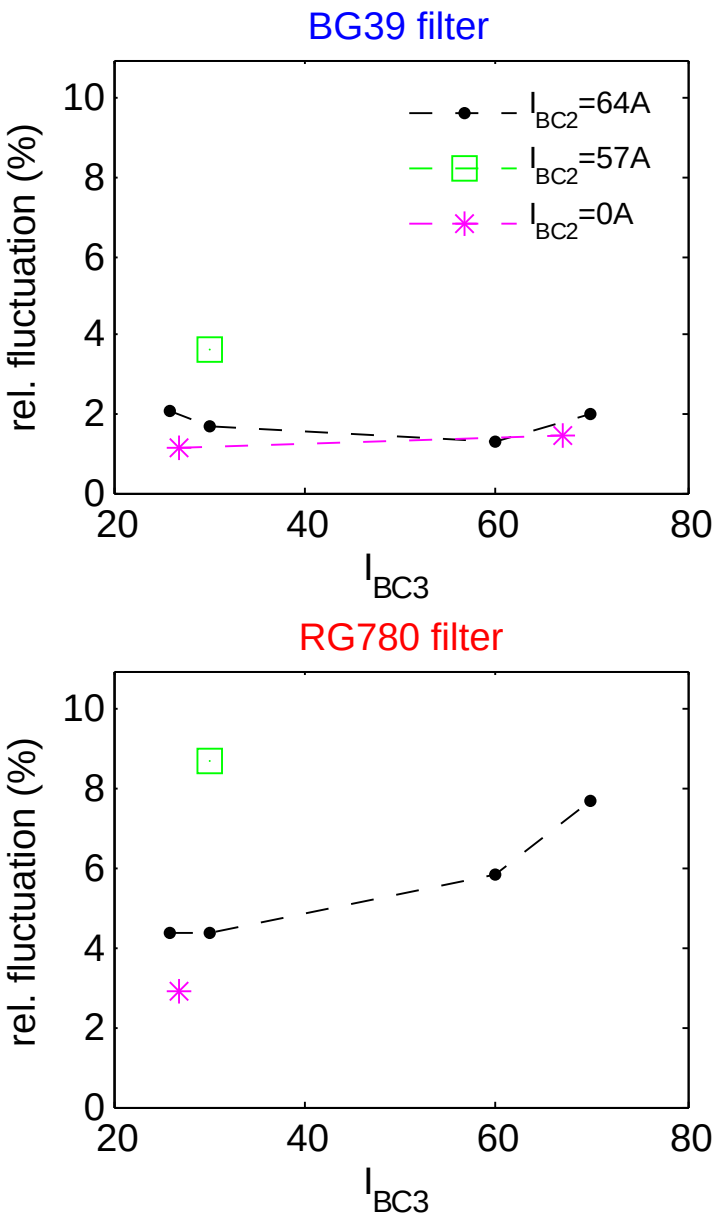
Σ ROI intensity:

→ intensity increases with decreasing BC3 current for all filters!

→ low BC2 current □ offers highest intensity in red regime

Note:
problems with saturation at oncrest phases!

OTR spectra III



Σ ROI fluctuation:

→ rel. fluctuations 1% to 2% for BG39

→ about 3% up to 4% for RG780 filter

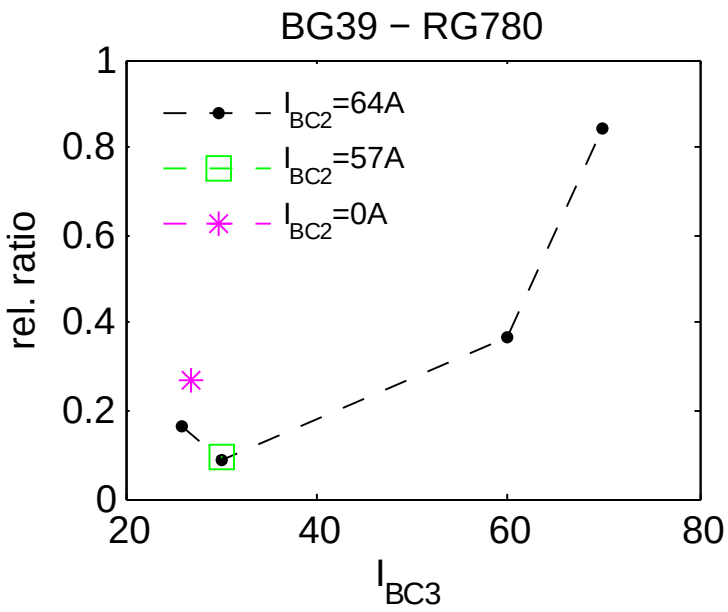
→ low current □ setting shows maximum fluctuations

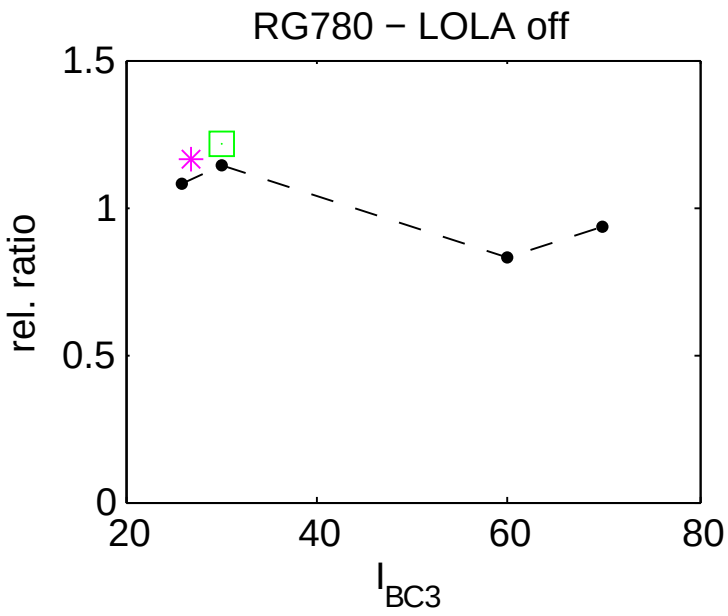
Note:

charge is stable around 1.3%

RG780 filter images at high current show weak intensity

OTR spectra V





Intensity ratios:

→ for decreasing BC3 current pronunciation in the red regime is significant

→ comparsion between TDS on - off reasonable

Conclusions

I. Coherent transition radiation signals reaches form the infrared into the optical wavelength regime!

II. Spectra and TDS images show rapid fluctuating structure!

III. R56 dependency

IR: increasing intensity for increasing $R56_{BC3}$
no obvious $R56_{BC3}$ dependency

O: increasing intensity for decreasing $R56_{BC3}$
both R56 at minimum value create maximum intensity
more intensified signal in the red spectral part

IV. Problem of the determination of incoherent OTR!

V. Problem with camera saturation occurs!