Powerful, Steady State, Coherent THz-Synchrotron Radiation at BESSYII

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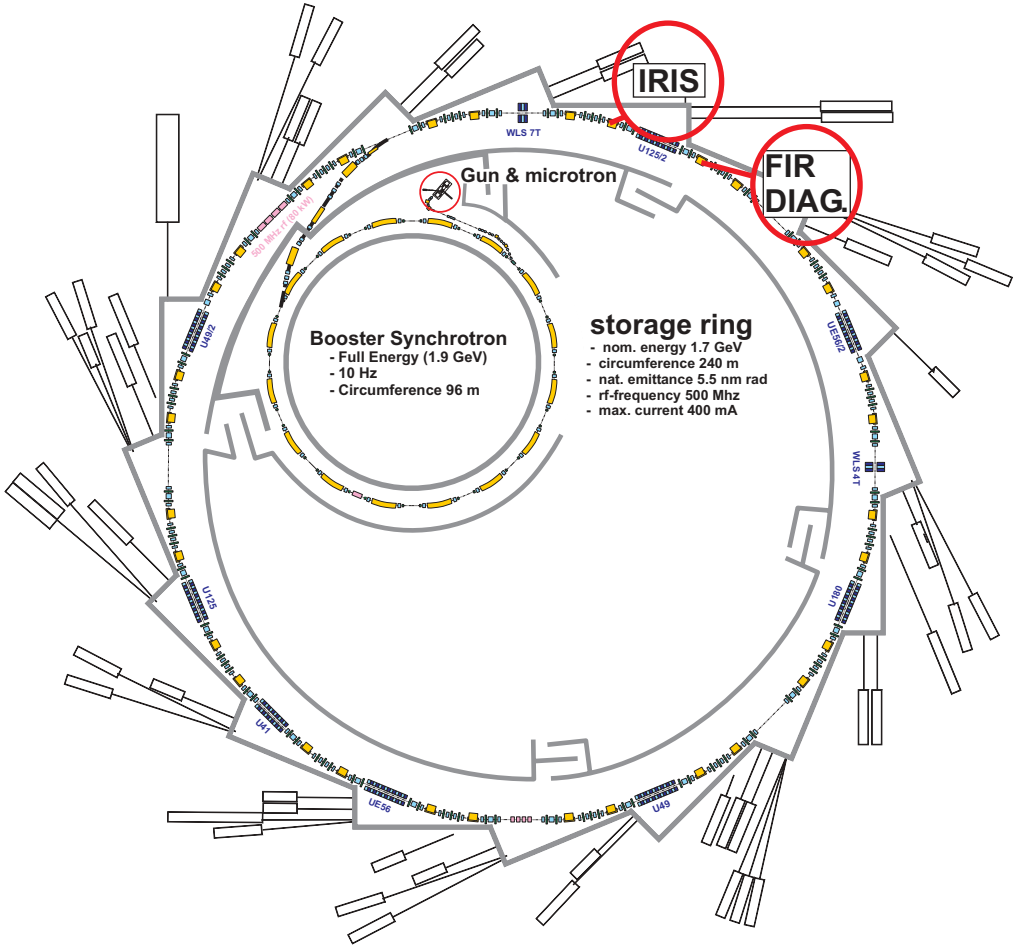
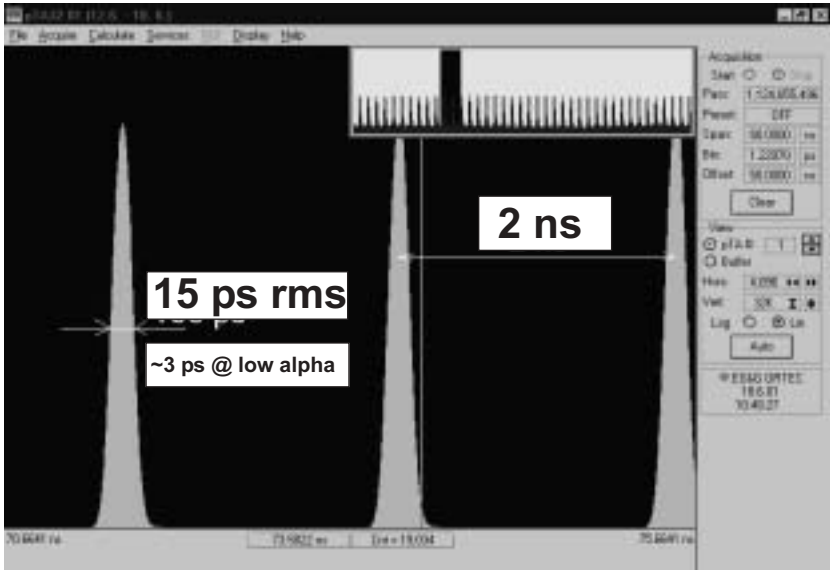
1. BESSY II storage ring
2. coherent radiation from electron bunches
3. experimental set up
4. characterization of the radiation
5. beam diagnostics with THz radiation
6. conclusion

BESSY II storage ring

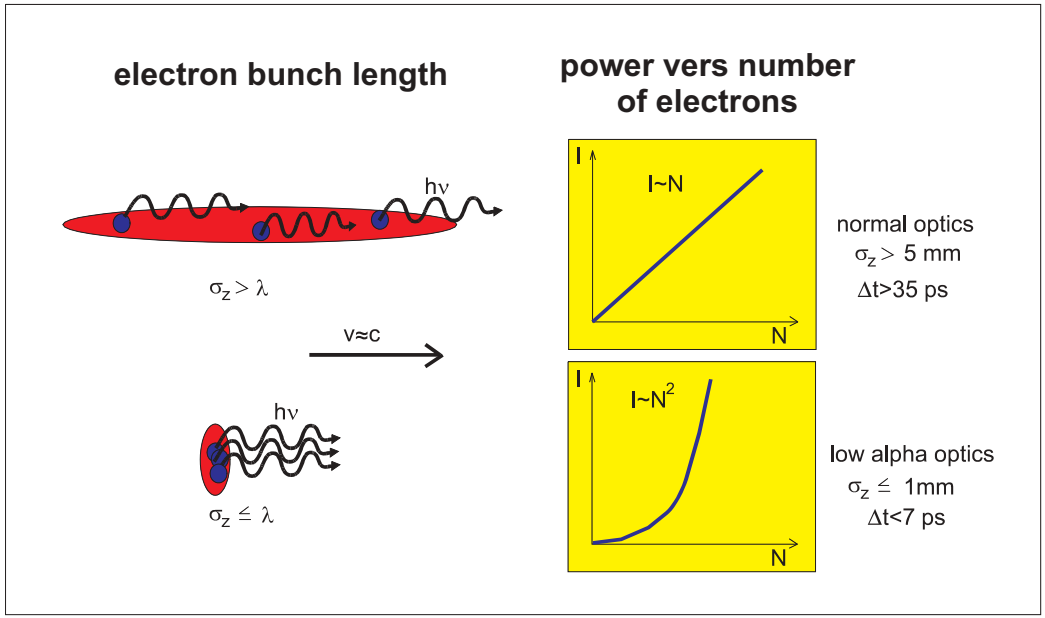
scheme of the storage ring with FIR ports

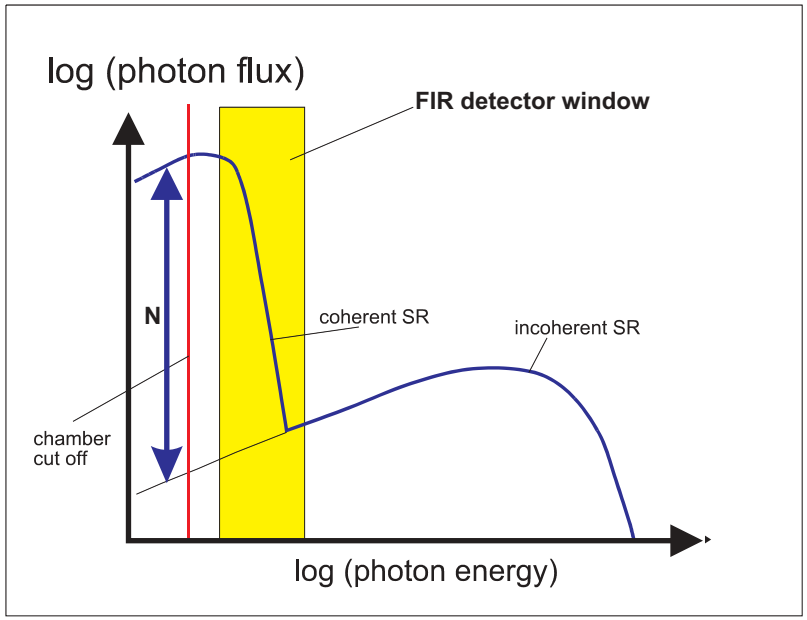


time structure:
400 rf-buckets
800 ns revolution time
1.25 MHz revolution frequency



Coherent radiation from electron bunches





emitted SR-power

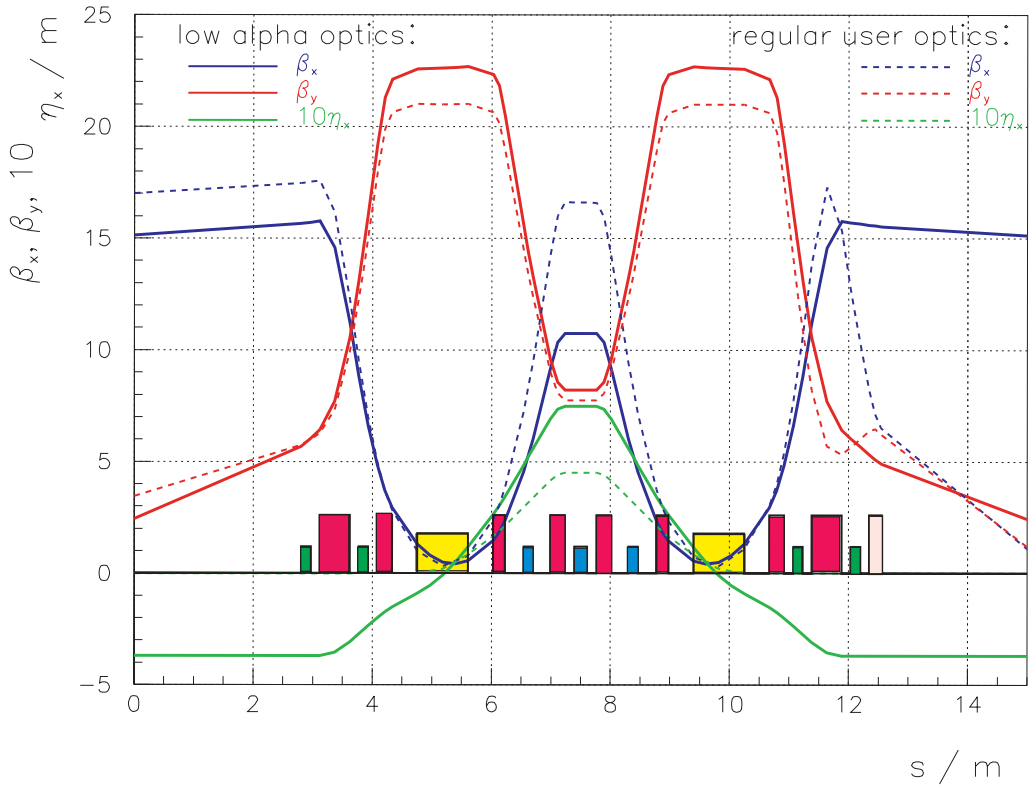
$$P = P_1 N(1 + N f)$$

N=number of electrons, f=form factor

f= power spectrum of longitudinal bunch density

incoherent P~N , coherent P~N^2

low alpha optics: dL/L= dp/p

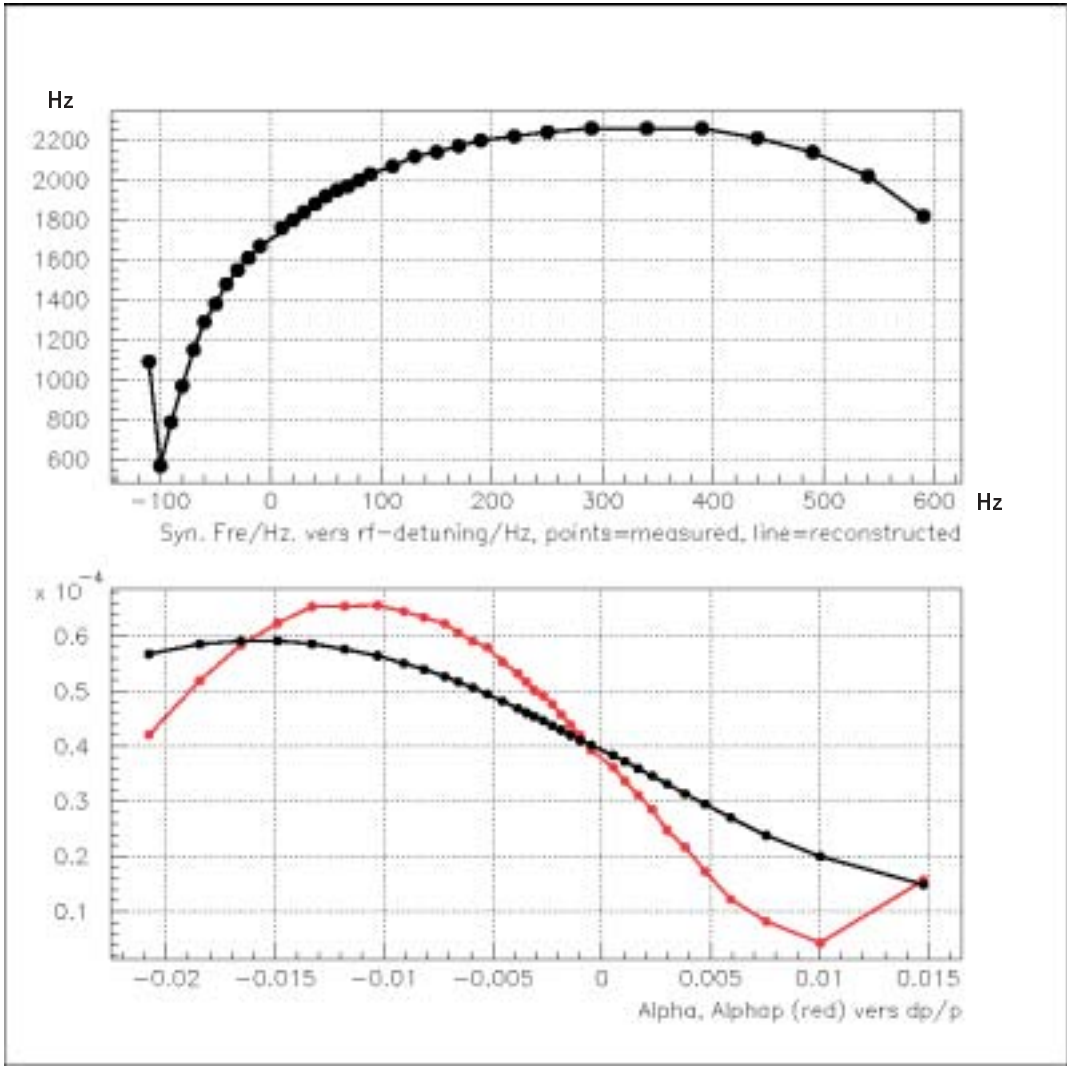


alpha [1/10**5]	synch. tune [kHz]
72	7.2
13	3.0
5.6	2.0
1.4	1.0
0.7	0.7
0.07	0.22

f_{sy}^2

dedicated optics for bunch manipulation
- bunch length from 5mm to ~1mm (rms)
- deviation from Gaussian shape

example: alpha dependency on momentum



synchrotron tune a s a function of the rf frequency

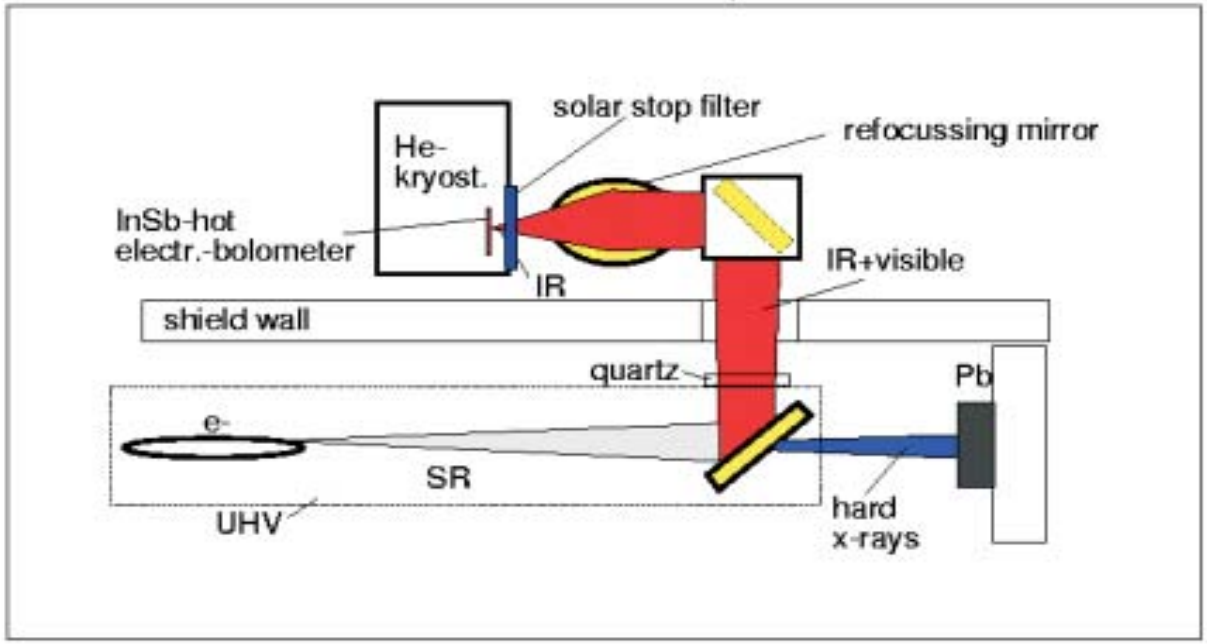
dots=experimental values,
line=reconstructed from derived alpha values

alpha a s a function of the momentum deviation

see PAC-1999 Feikes & Wuestefeld for the method of the measurement

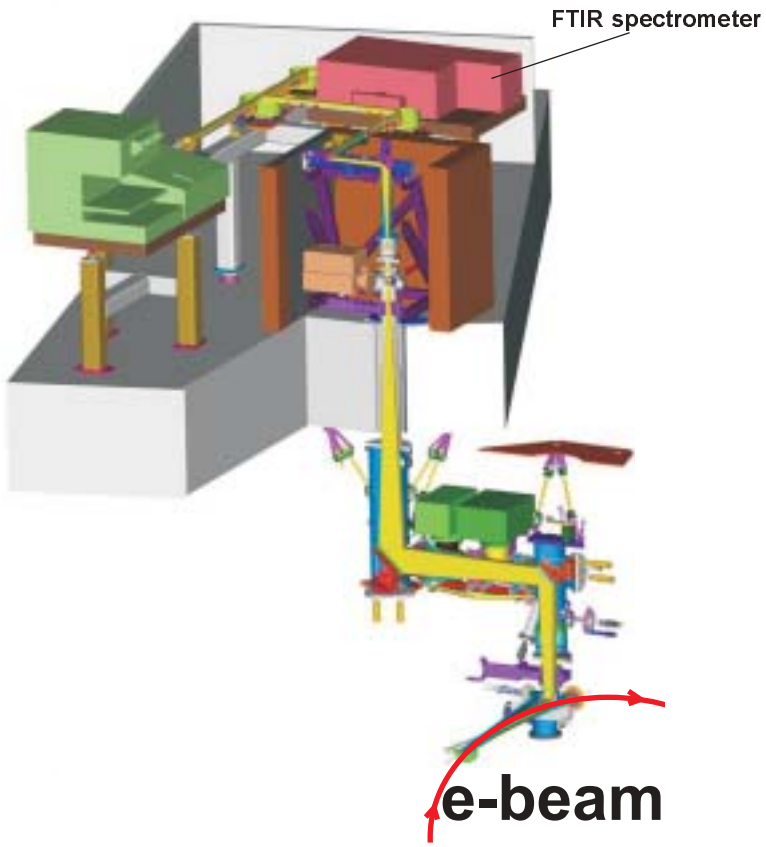
experimental set up

FIR diagnostic port



acceptance 10 mrad^2

IRIS beamline

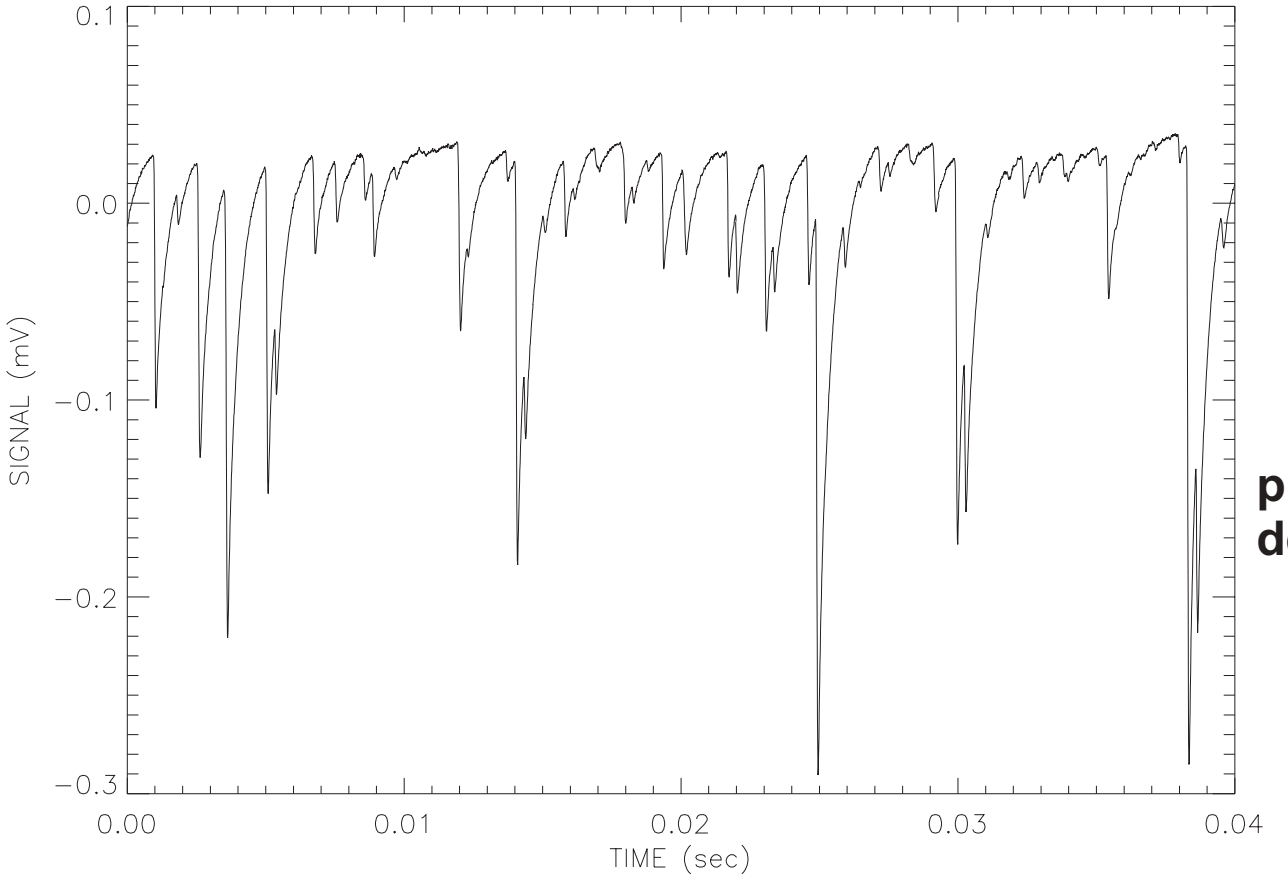


acceptance 40x60 mrad^2

LHe-cooled detectors

Si-bolometer (IRIS) =1 ms

CSR in user optics, bursting emission

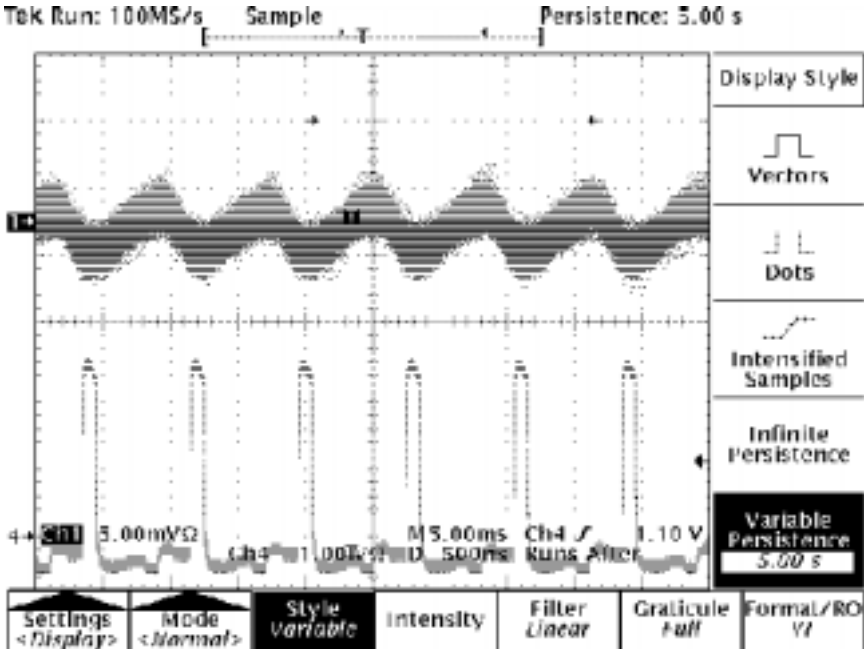


pulse shape given by the detector time constant

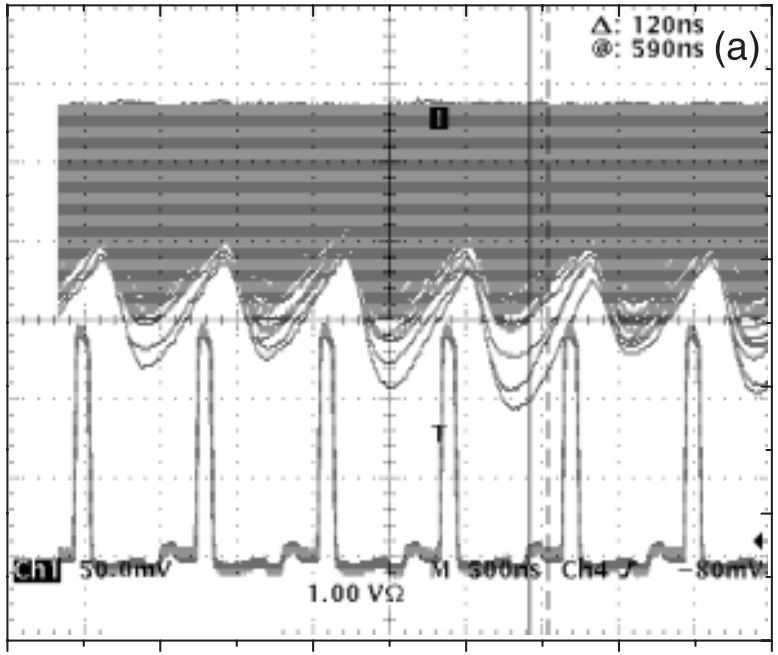
LHe-cooled detectors

InSb-bolometer 1 µs

CSR low alpha mode
steady state emission



CSR user optics mode
bursting emission

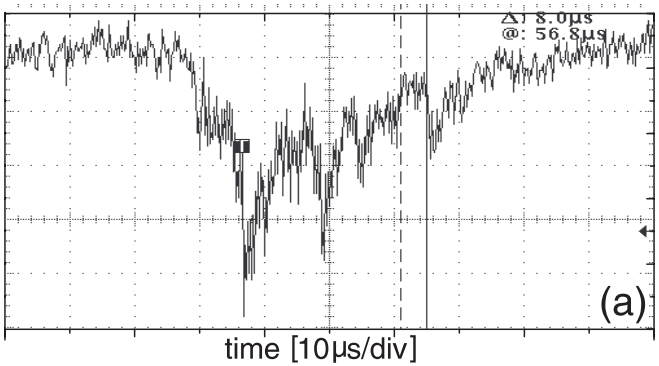


see Phys. Rev. Lett. 88, 2548011-2548014, 2002

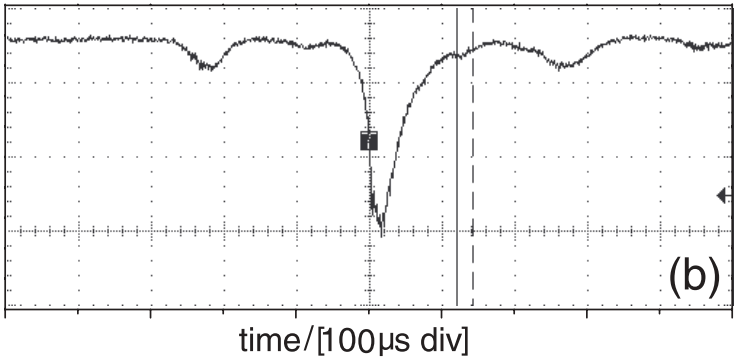
LHe-cooled detectors

InSb-bolometer 1 µs

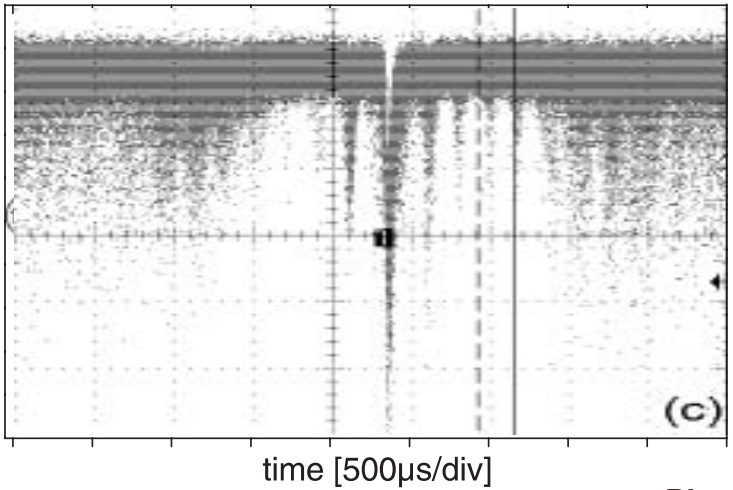
user optics: burstings CSR emission



time resolved burst



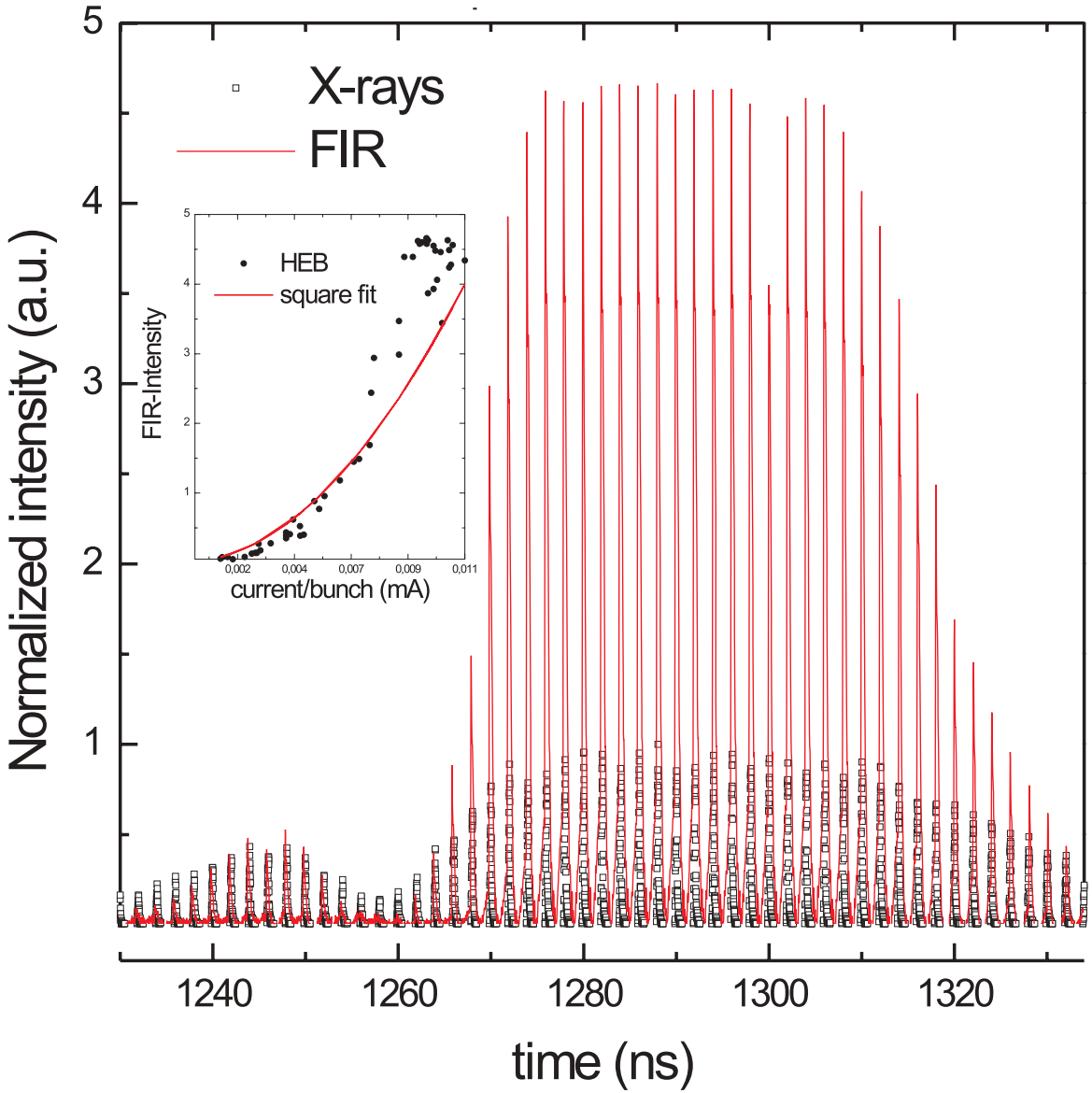
time-averaged bursts



correlation between adjacent bursts

see Phys. Rev. Lett. 88, 2548011-2548014, 2002

LHe-cooled detectors



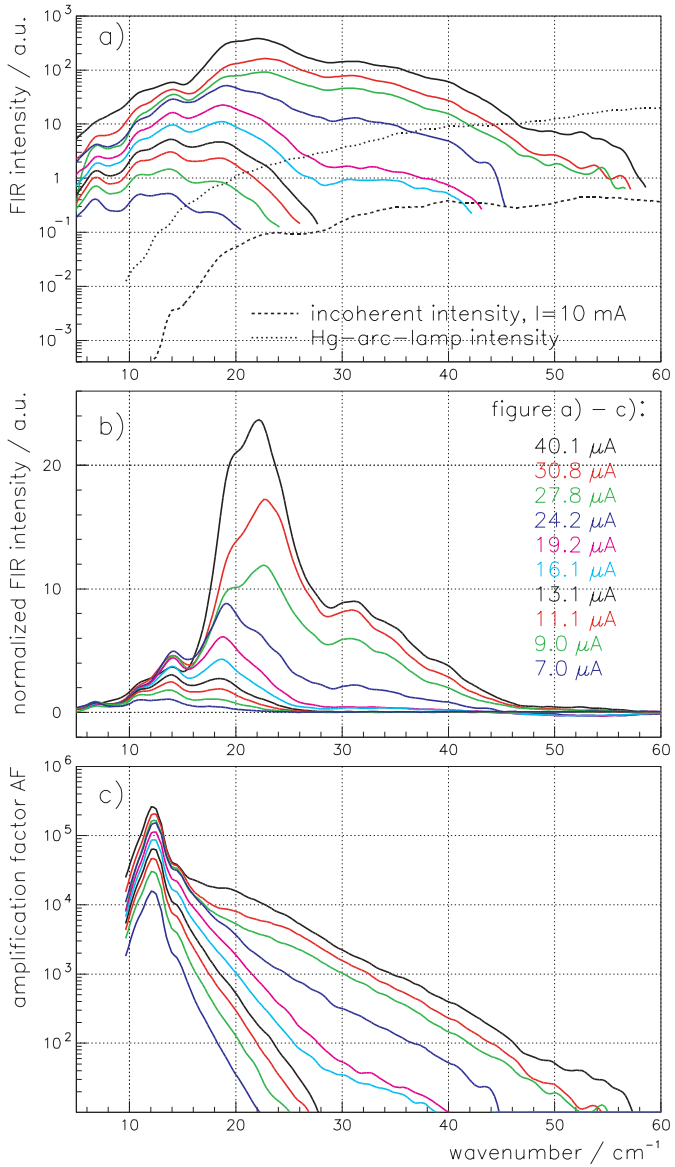
HEB (DLR), =20 ps

example:
bunch resolved THz-emission

synchr. frequency=1.8 kHz
5.8 mA and 52 bunches

black dots = bunch current signal
red lines = infrared signal
bunch separation = 2ns

characterization of the radiation



measured spectral content

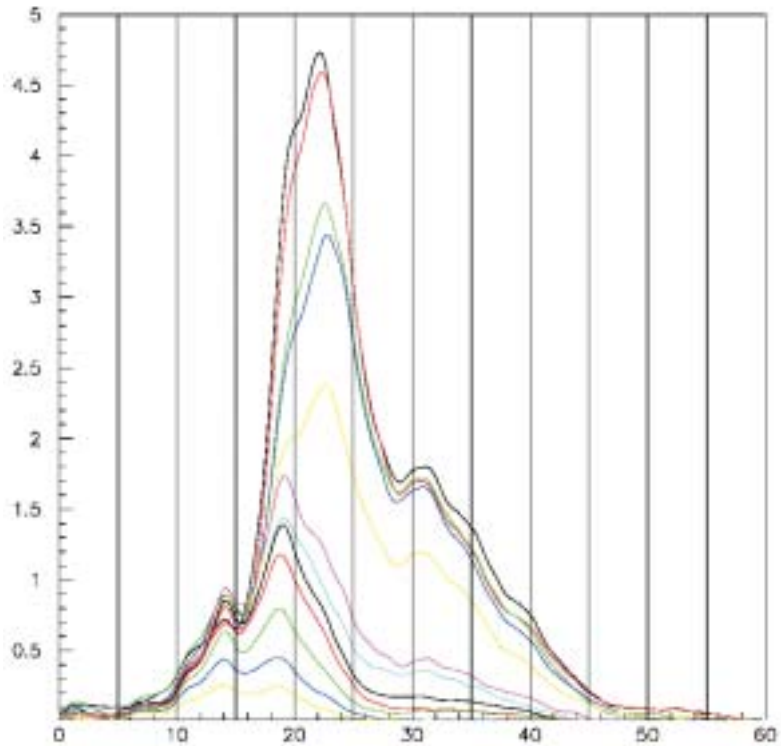
EPAC 2002, Abo-Bakr et al.

- current dependence of spectra and gain coherent/incoherent

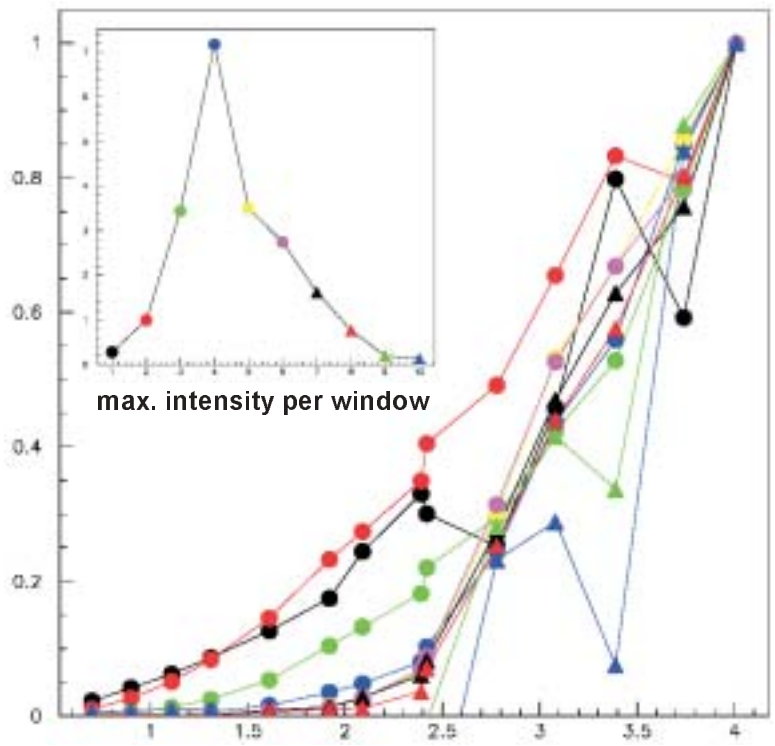
- emitted power grows stronger than N^2
  total power ~1 mW (100 bunches)
  ~about 1/4000 of total emitted power

- power gain up to 100 000 compared to incoherent power

current threshold of the powerspectrum



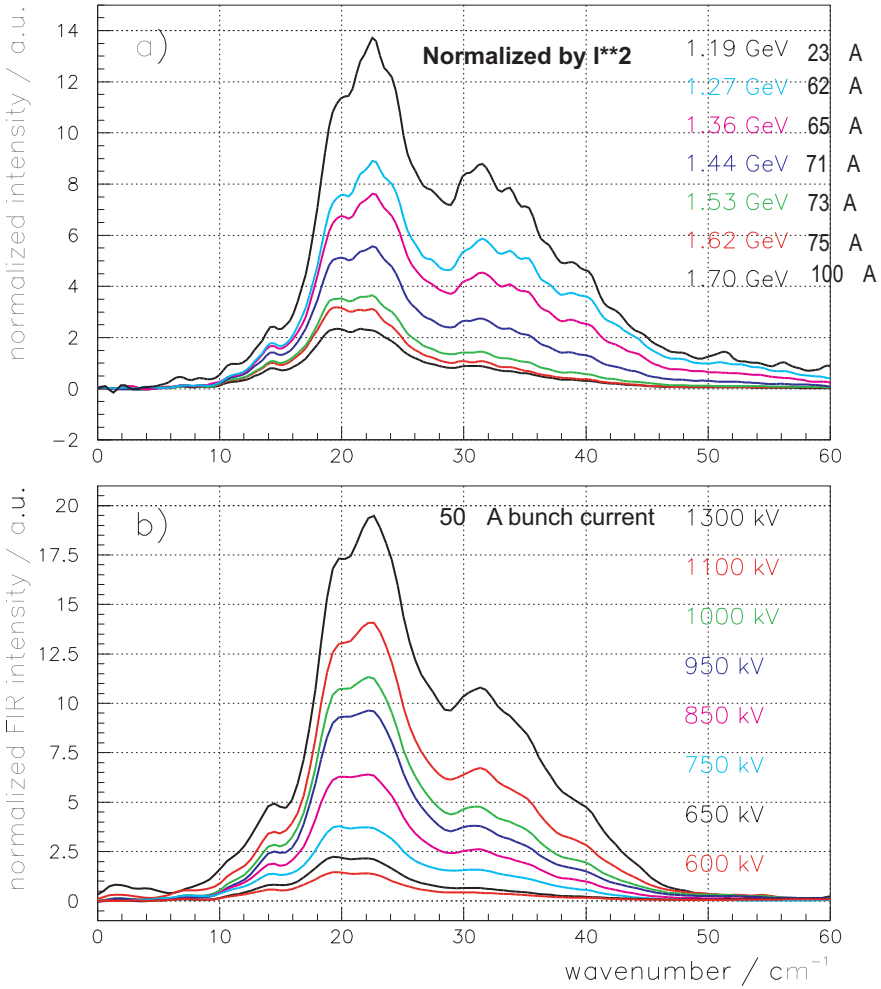
current dependence of powerspectrum



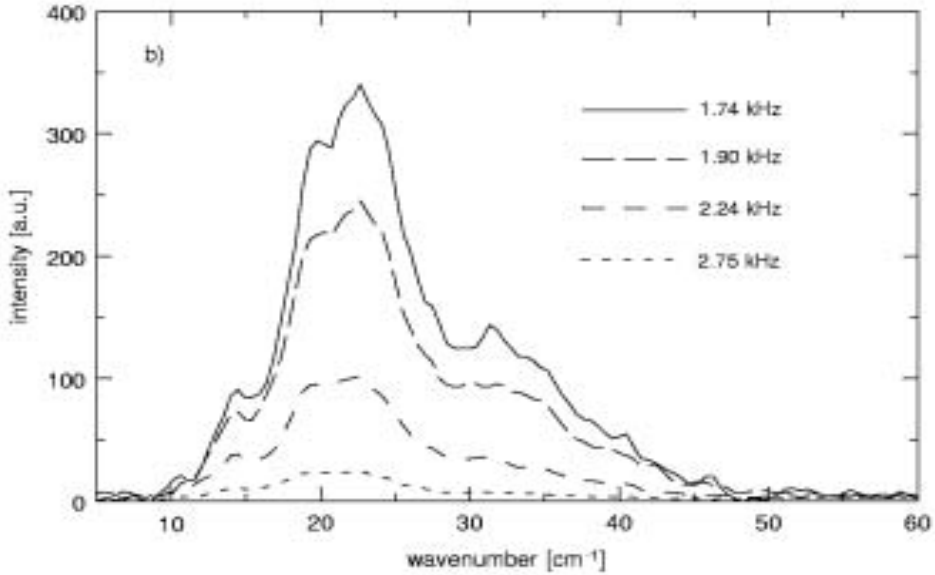
fractional threshold of powerspectrum

spectral dependency on basic parameters

rf-voltage and energy dependence of the spectra



-dependency



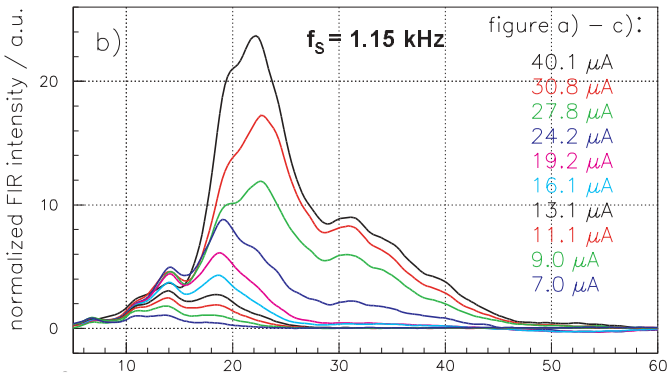
energy 1.7 - 1.19 GeV, fs(max)=1.9kHz

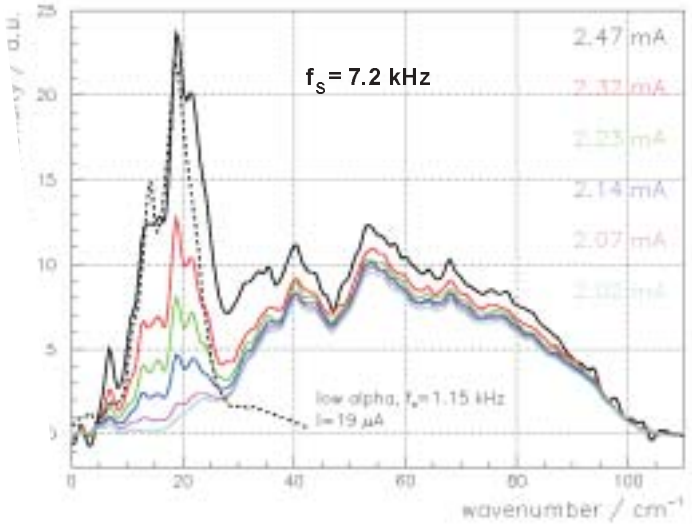
- **10 times more power changing rf-voltage 0.6 keV - 1.3 keV fs(max)=1.1kHz, I=0.05mA/bunch**

- **14 times enhancement changing the from $1 \cdot 10^{-3}$ to $0.4\ 10^{-3}$**

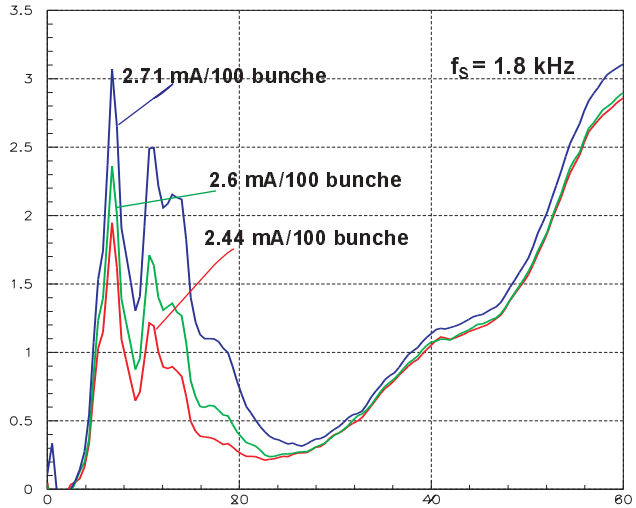
power spectra generated by different beam optics and at different currents

power spectra in low alpha optics





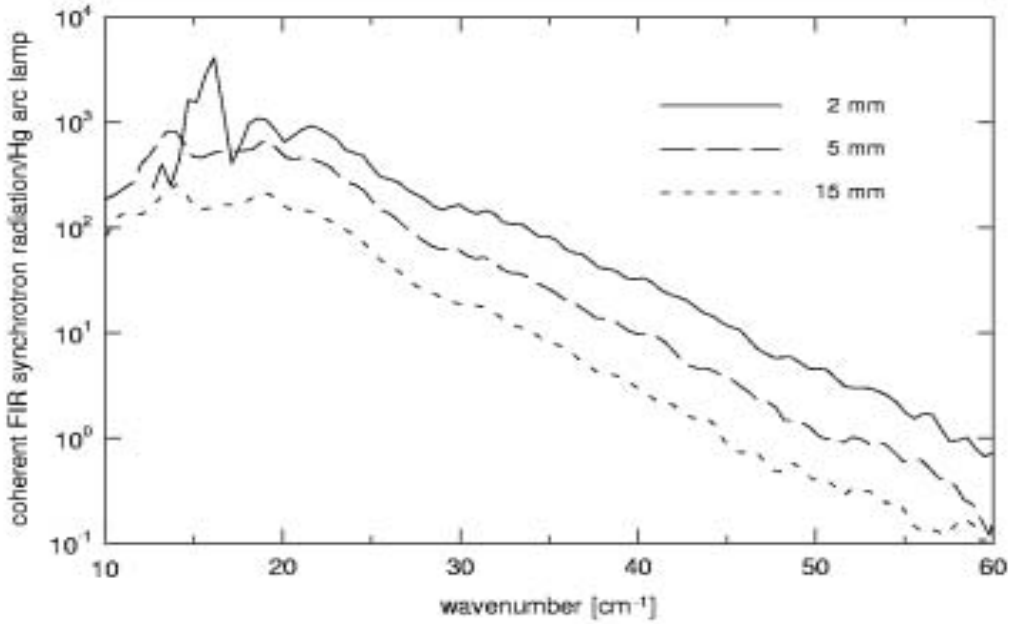
power spectra in
user optics optics



power spectra in
neg. low alpha optics

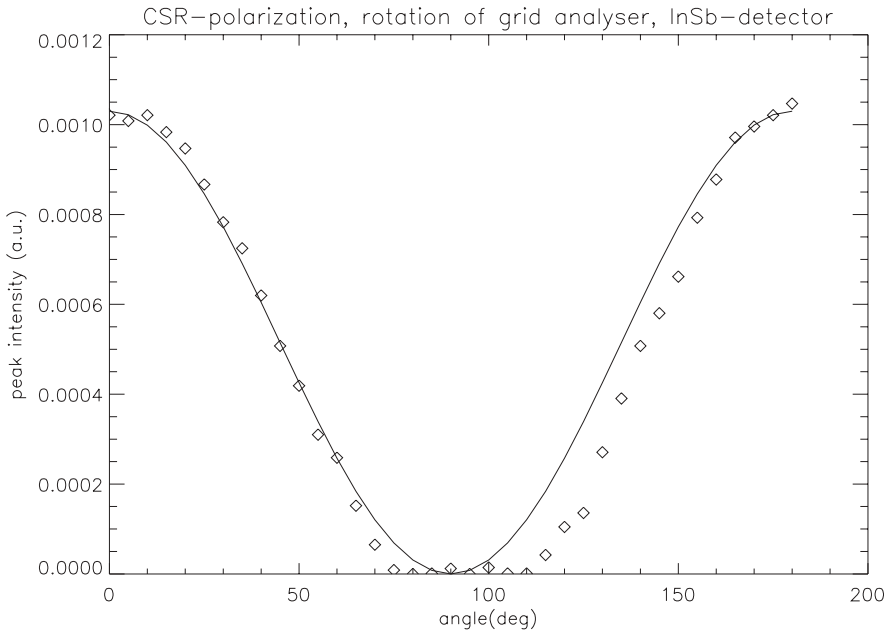
characterization of the radiation

CSR brillance compared with Hg-lamp



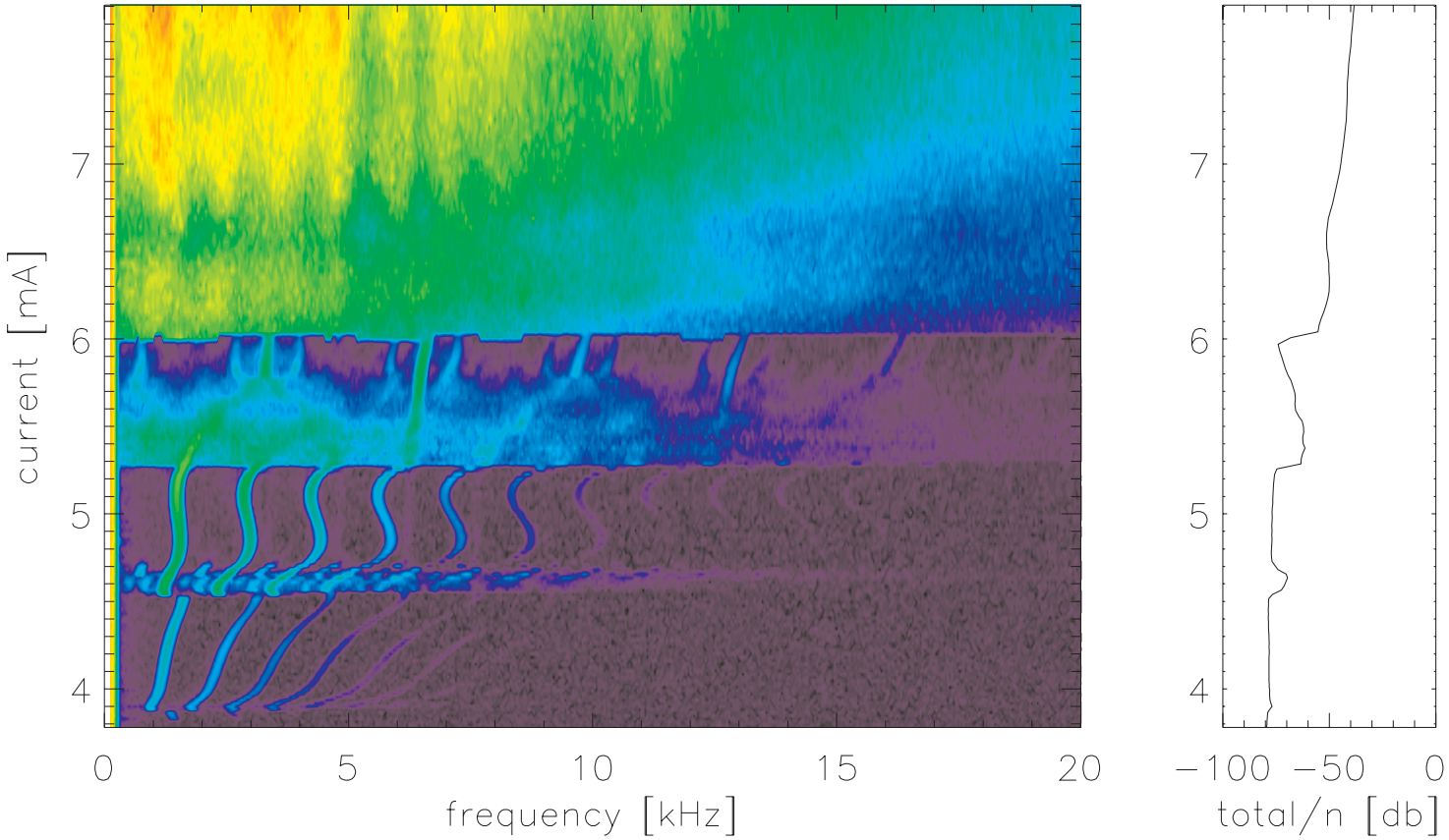
up to 1000 more THz power can be focussed to a 2 mm aperture compared to Hg-lamp

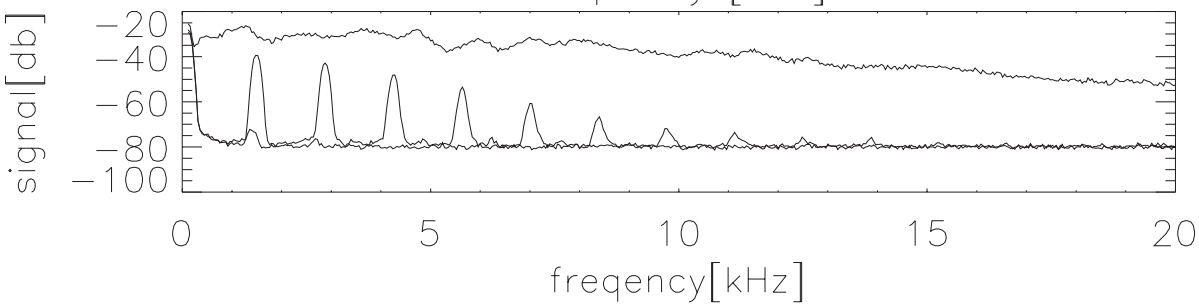
CSR polarization at FIR diagnostic port



coherent radiation shows 98% polarization degree in the ring level as expected for incoherent radiation

detecting electron beam instabilities and thresholds. Transition of periodic to chaotic bursting in single bunch mode





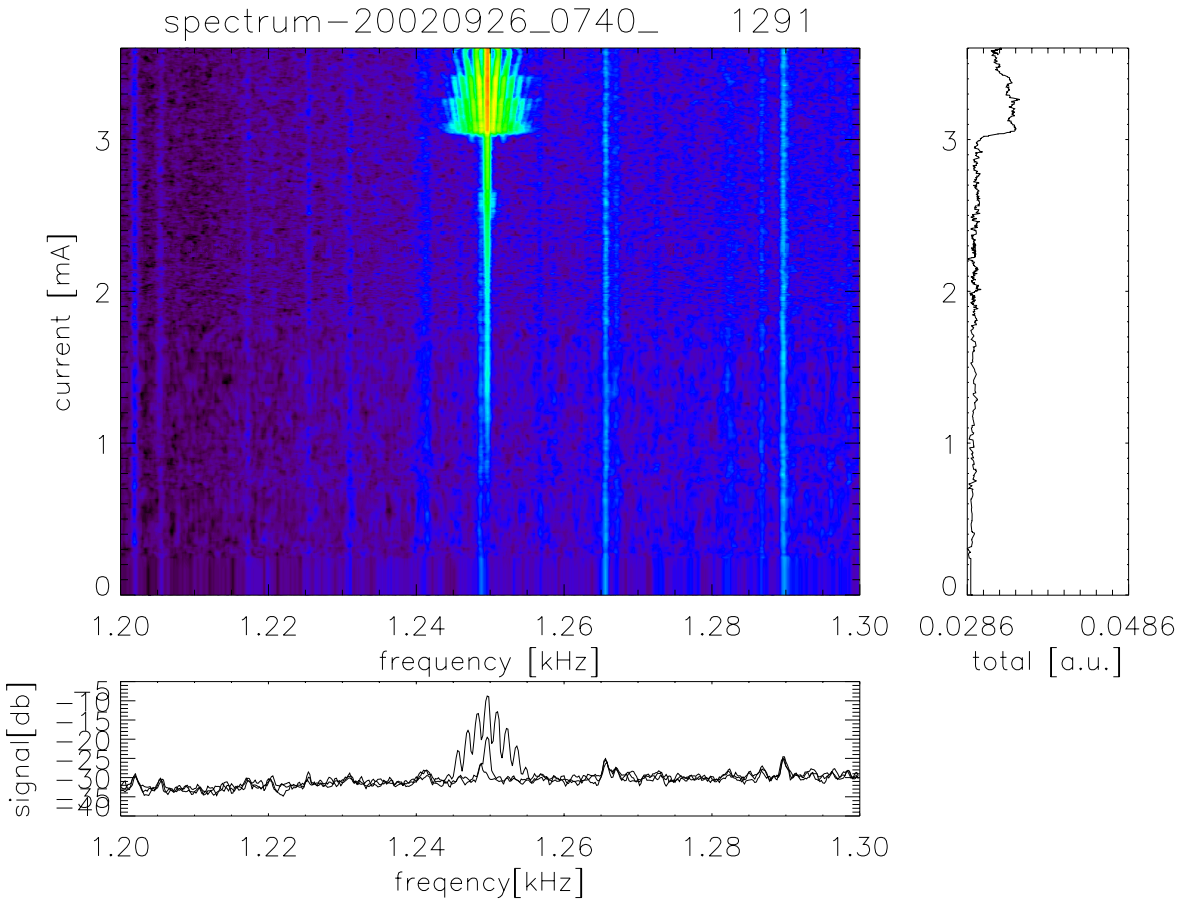
InSb-detector (BESSY, at Diagnostic Beamline) normal user optics with synchrotron frequency of 7.2 kHz. Transition from periodic bursting to bursting with increasing current

comments to foils 17 to 20:

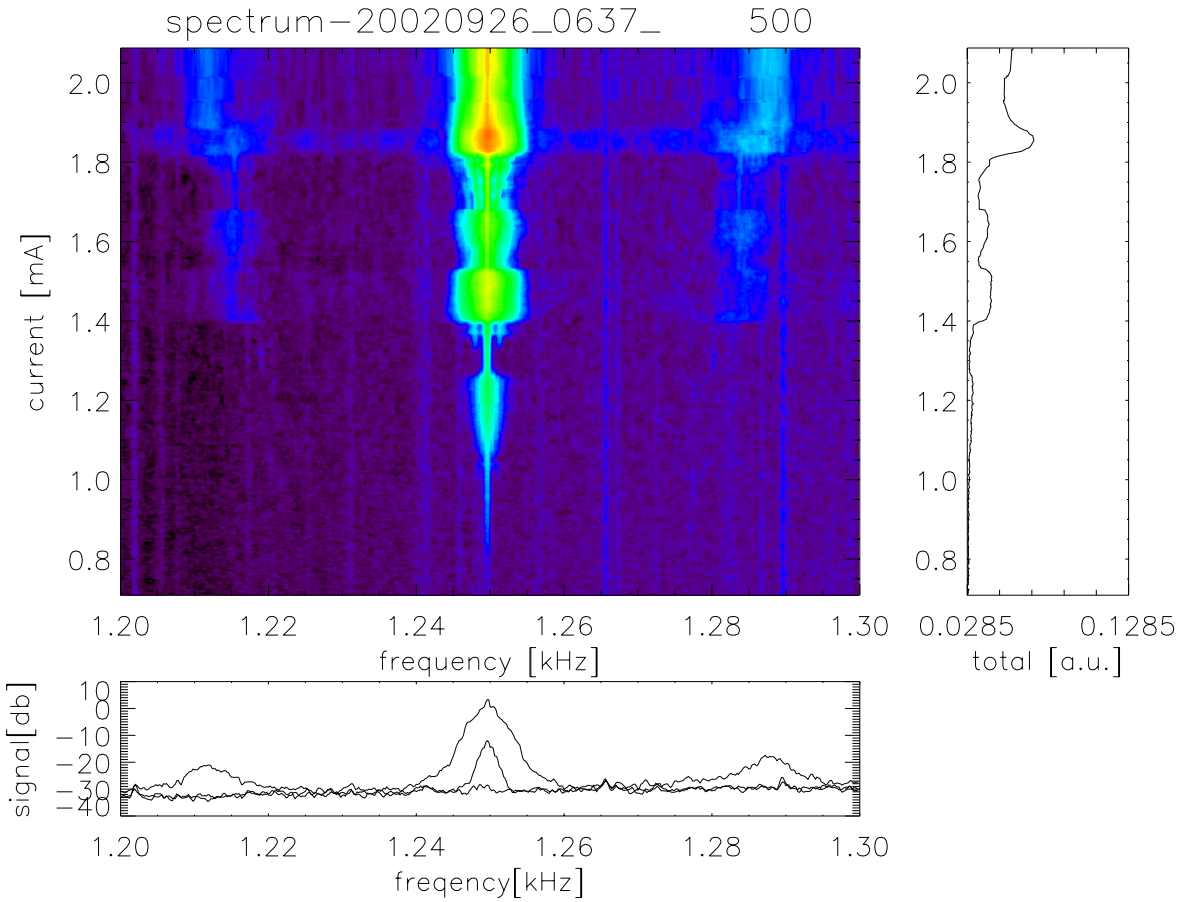
on the following foils single bunch threshold currents for periodic and bursting THz radiation are shown. The different records were performed at different alpha values, indicated by the synchrotron frequency fs:

foil 17 at 7.2 kHz
foil 18 at 5 kHz
foil 19 at 3 kHz
foil 20 at 2.1 kHz

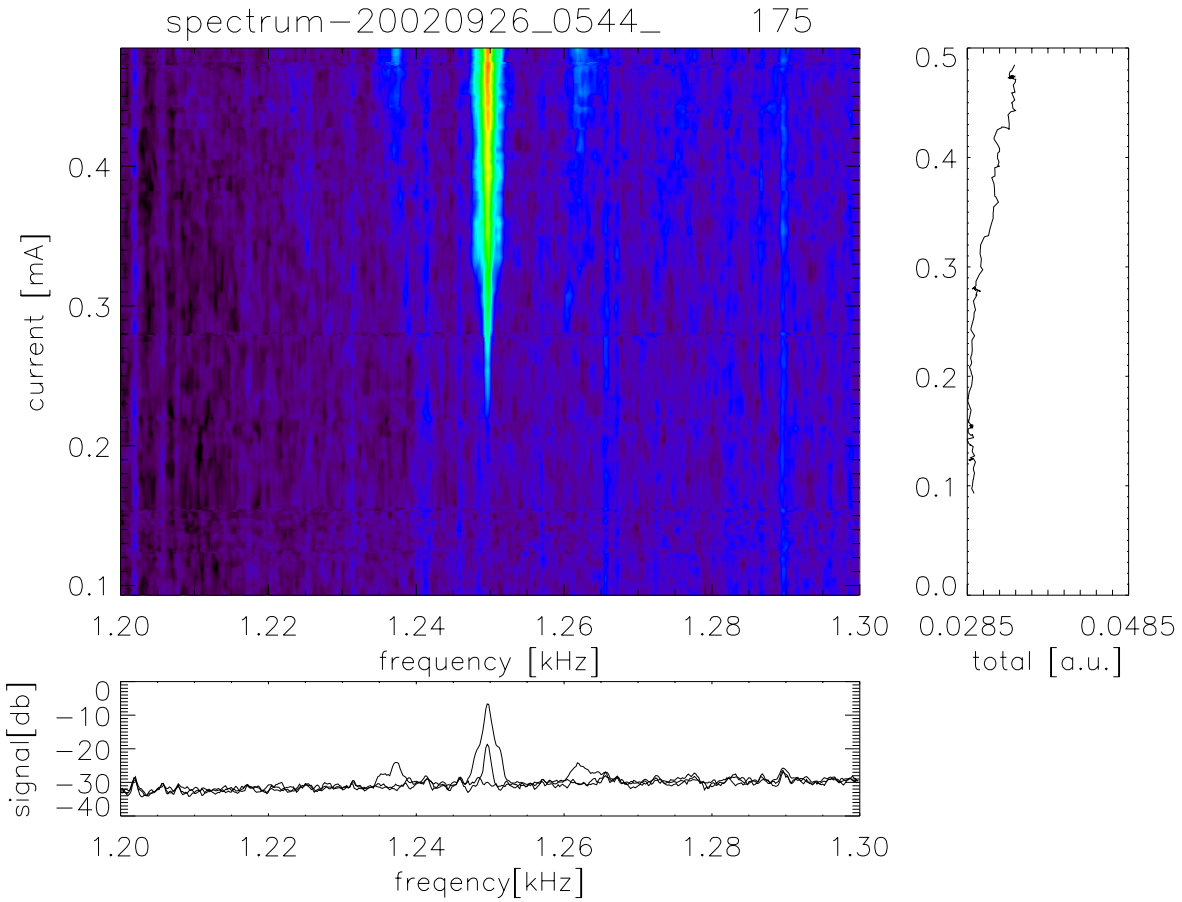
the vertical axis is the single bunch current, the horizontal axis is the frequency span in MHz (not in kHz as printed on the foil), a fixed interval of plus/minus 50 kHz. The signals are recorded with an InSb detector at the revolution frequency of the single bunch of 1.25 Mhz. Sidebands of the revolution frequency are visible, indicating bunch instabilities

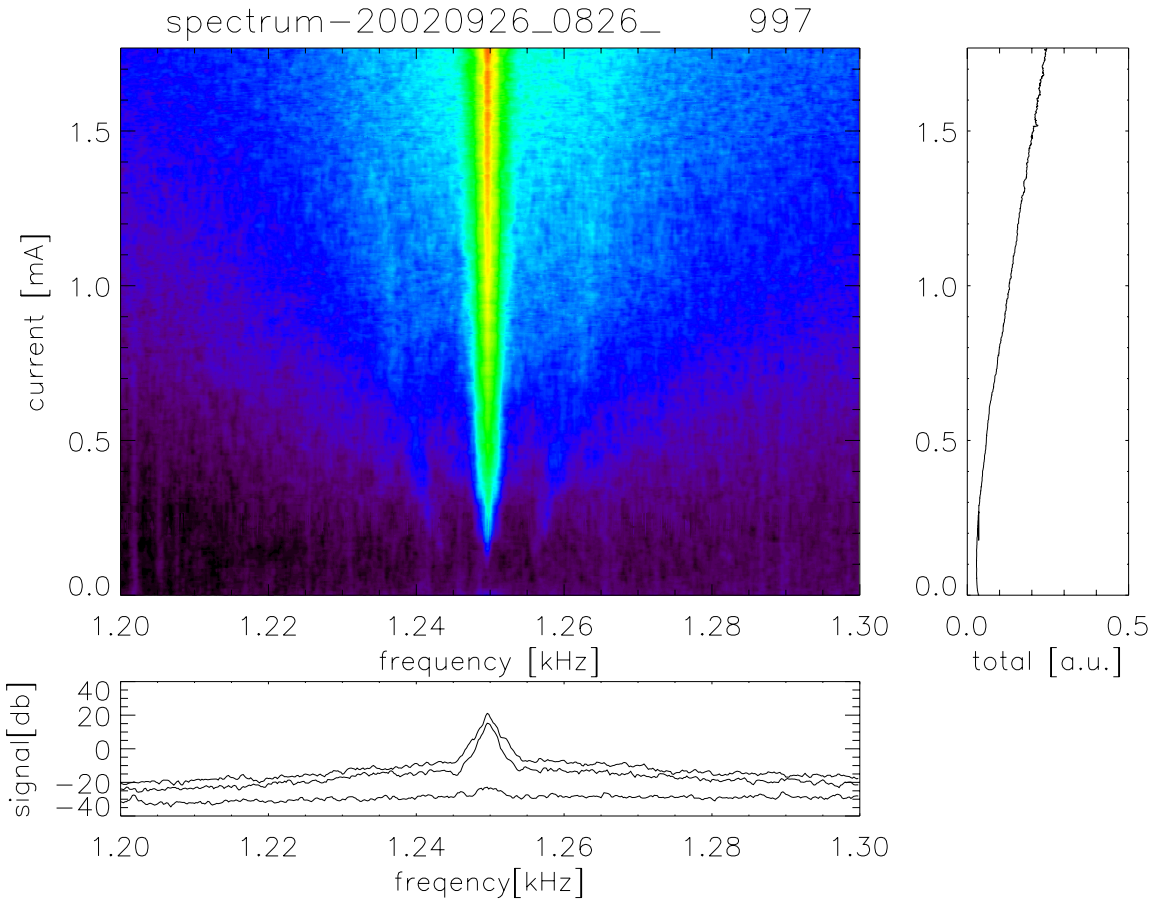

spectrum−20020926_0740_ 1291
current [mA]
0
1
2
3
1.20
1.22
1.24
1.26
1.28
1.30
frequency [kHz]
0.0286
0.0486
total [a.u.]

signal[db]
1.20
1.22
1.24
1.26
1.28
1.30
freqency[kHz]


spectrum−20020926_0637_ 500
current [mA]
2.0
1.8
1.6
1.4
1.2
1.0
0.8
1.20
1.22
1.24
1.26
1.28
1.30
frequency [kHz]
0.0285
0.1285
total [a.u.]

signal[db]
10
0
−10
−20
−30
−40
1.20
1.22
1.24
1.26
1.28
1.30
freqency[kHz]

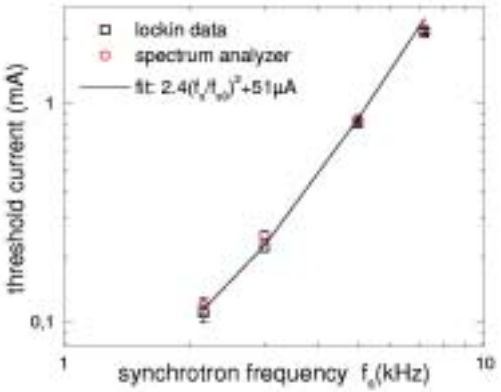

spectrum−20020926_0544_ 175
current [mA]
0.1
0.2
0.3
0.4
1.20
1.22
1.24
1.26
1.28
1.30
frequency [kHz]
0.0
0.1
0.2
0.3
0.4
0.5
0.0285
0.0485
total [a.u.]
signal[db]
0
−10
−20
−30
−40
1.20
1.22
1.24
1.26
1.28
1.30
freqency[kHz]


spectrum−20020926_0826_ 997
current [mA]
1.5
1.0
0.5
0.0
1.20
1.22
1.24
1.26
1.28
1.30
frequency [kHz]
0.0
0.5
total [a.u.]
signal[db]
40
20
0
−20
−40
freqency[kHz]

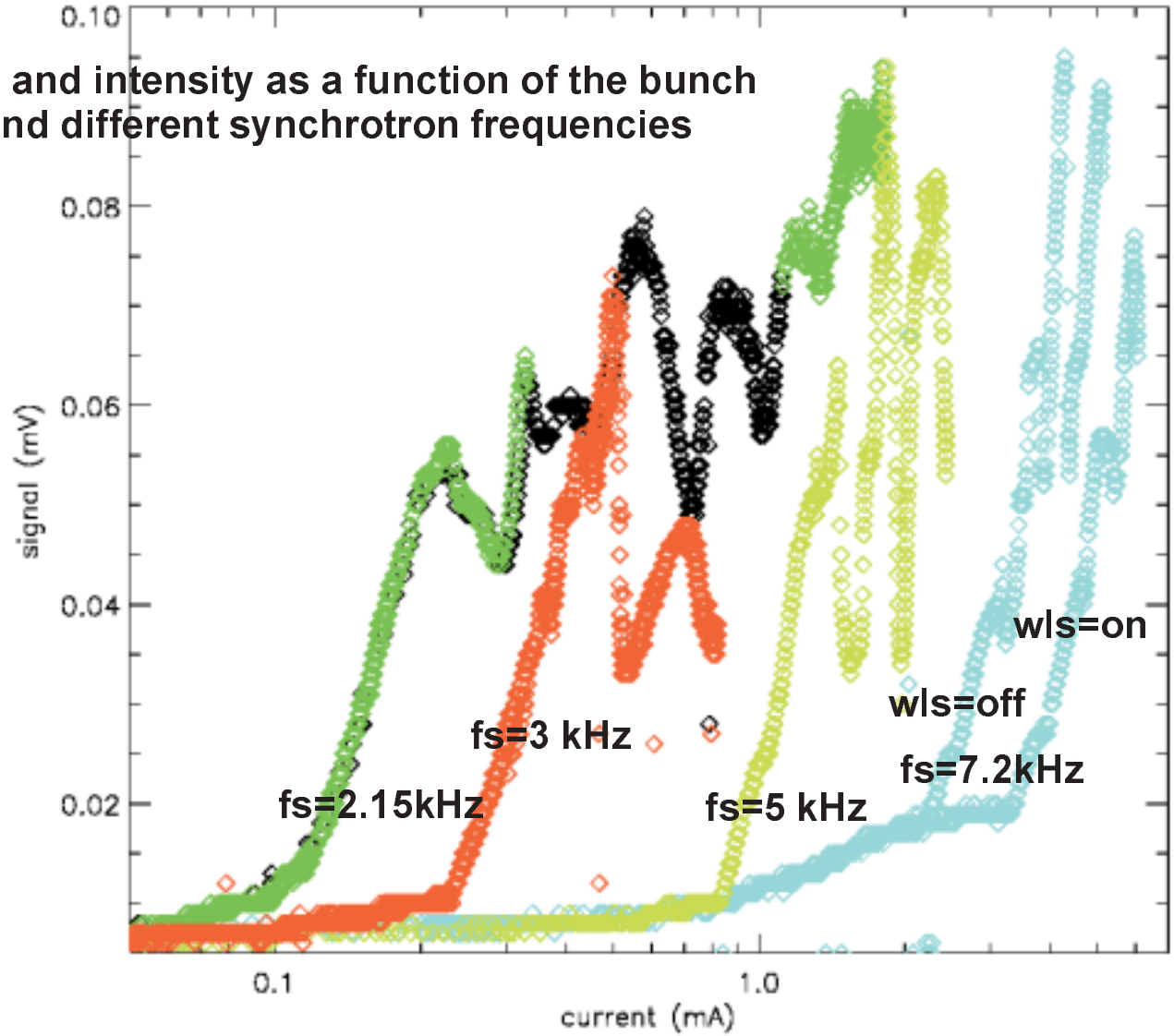
Single bunch CSR-signal at 1.25 MHz and ~5Hz bandwidth

threshold and intensity as a function of the bunch current and different synchrotron frequencies

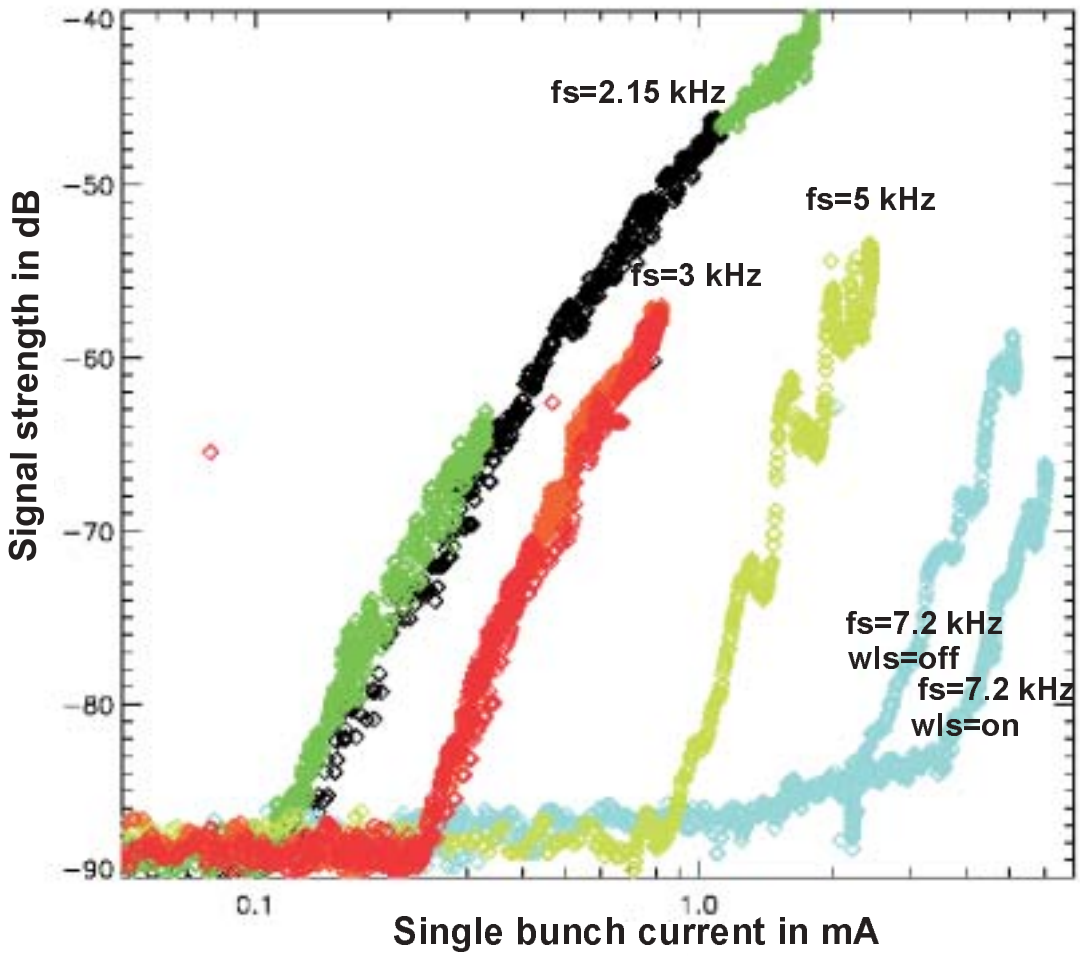
fit to the current threshold as a function of the synchrotron frequency



in agreement with Stupakov & Heifets, PRST-AB 5, 054402 (2002)



single bunch CSR-intensity and threshold at 1.25MHz and 300Hz bandwidth



wls=superconducting wavelength shifter

Beam and instability parameters for ALS and BESSY II

see Stupakov & Heifets, PRST-AB 5, 054402, 2002

	ALS	BESSY II
E/GeV	1.5	1.7
	1.4E-3	0.73E-3
	7E-4	7E-4
<R>/m	31.3	38.2
R/m	4	4.35
b/cm	1	1.75
I_b/mA	30	15
$_z$/cm	0.7	0.5
/m	1.2E3	1.6E3
R/b	400	250
R/(2 **1.5)	4.7E-5	3.4E-5

conclusion

stable CSR at electron storage rings opens a new, very promizing technique of THz generation
- spectral range 5 - 50 1/cm
- power during pulse > 2.5 Watt (stable CSR)
- avarage power ~ 1 mWatt (stable CSR)
- short pulses of ~3 ps-rms-length

with increasing bunch current the CSR power growths, approaching the bursting threshold the CSR emission is
- stable - periodic bursting - stochastic bursting