Scanning Problems of FLARE, a THz-FEL with a waveguide

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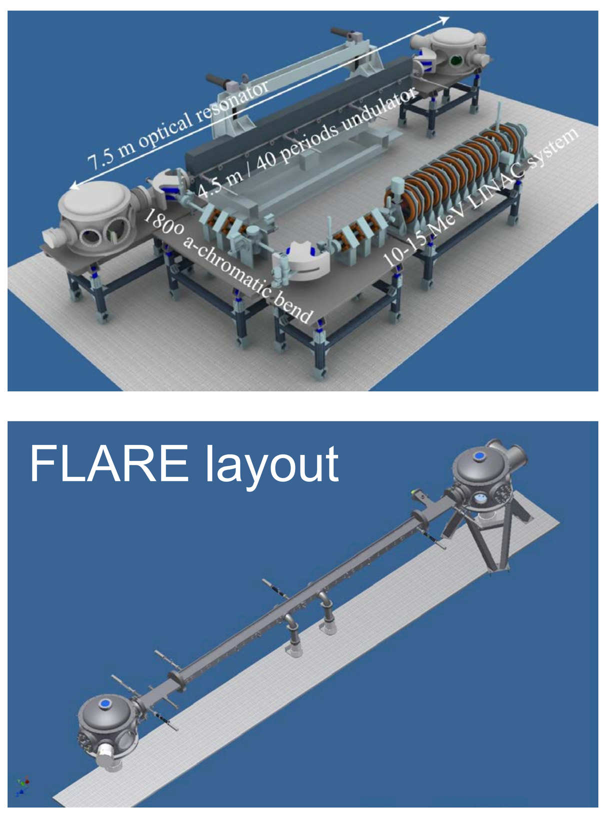
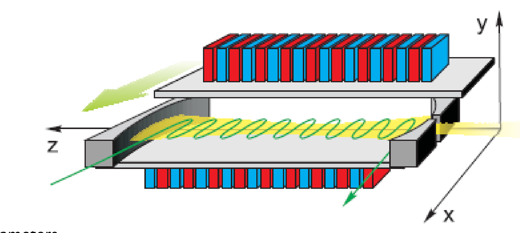


E-beam parameters

Micropulse rep. rate†	GHz	2.998
Macropulse rep. rate	Hz	≤ 10
Macropulse duration	μs	< 12
Electron beam energy	MeV	10 to 15
Energy spread (rms)	%	≈ 0.3
Electron bunch duration (rms)	ps	few
Macropulse current	A	0.6
Normalized emittance	mm mrad	≈ 50
Electron bunch charge	pC	200

† recently also 20 MHz



FEL parameters

Undulator period	mm	110
Number of undulator periods		40

Cavity length	mm	7500
Cavity mirrors width	mm	200
Cavity mirrors radii of curvature	mm	4810
Rayleigh range	mm	2000
Waveguide gap	mm	10
Waveguide wall material	Stainless steel	

Low-loss π-polarized resonator eigenmodes:

$$\Psi_{m,n}(x,z) = \frac{1}{norm} H_m \left(\sqrt{2}\,\frac{x}{\omega_n(z)}\right) \cdot exp\left[-\frac{x^2}{\omega_n(z)^2} - i\,\frac{k_{z,n}x^2}{2\rho_c(z)} + i\psi_m(z)\right] sin(k_\perp y)$$

FEL resonance condition: $(k_{z,n} + k_u + g_m)\beta_z - k = 0$

fast wave $$k^f_{m,n} = \frac{\beta_z \cdot g_m}{1-\beta_z^2} \cdot \left[1 + \beta_z \sqrt{1 - \frac{1-\beta_z^2}{\beta_z^2 \cdot g_m^2} \cdot \left(\frac{k_{\perp,n}}{k_u}\right)^2}\right]$$

slow wave $$k^s_{m,n} = \frac{\beta_z \cdot g_m}{1-\beta_z^2} \cdot \left[1 - \beta_z \sqrt{1 - \frac{1-\beta_z^2}{\beta_z^2 \cdot g_m^2} \cdot \left(\frac{k_{\perp,n}}{k_u}\right)^2}\right]$$

$l_u = undulator\ period$

$d = gap\ between\ plates$

$L_R = Rayleigh\ range$

$k_u = \frac{2\pi}{l_u}$

$k_{\perp,n} = n \cdot \frac{\pi}{d}$

$$\beta_z = \sqrt{1 - \frac{1-a_w^2}{\gamma^2}}$$

$$g_m = \left(1 - \frac{m+0.5}{k_u \cdot L_R}\right)$$

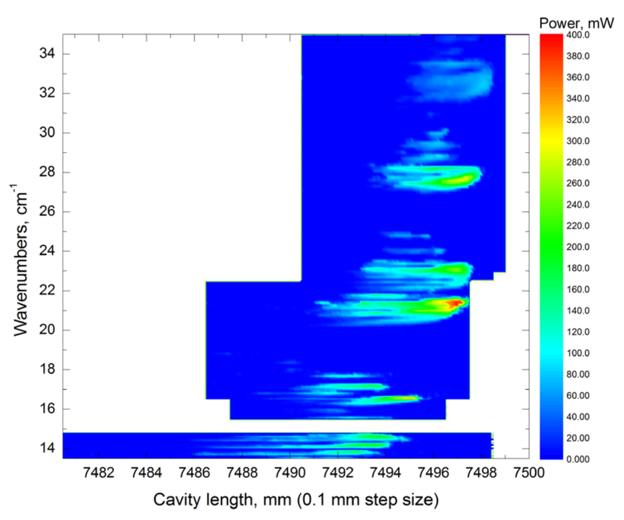
$$(k^{f,s})^2 = \left(k_z^{f,s}\right)^2 + k_\perp^2$$

Remarks:

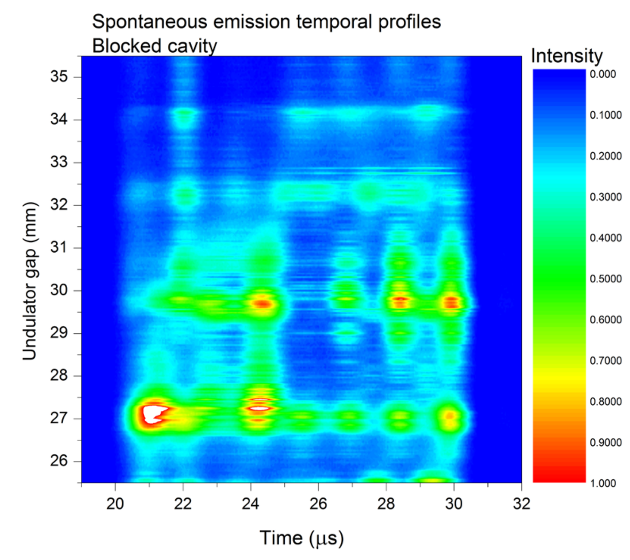
- *no solution for n=2 for $k/2\pi < 20$ cm^{-1}*
- *no solution for n>2 for $k/2\pi < 50$ cm^{-1}*
- *$k^s/2\pi < 2.5$ cm^{-1}*
- *@ 15 MeV and 20 cm^{-1}:*
  - *$\Delta m = 2 \rightarrow -0.4$ cm^{-1}*
  - *Group velocity $v_g/c = 0.9997$*
  - *v_g dispersion: 0.5 mm/cm^{-1} per roundtrip*

The problem:

FEL tuning gaps

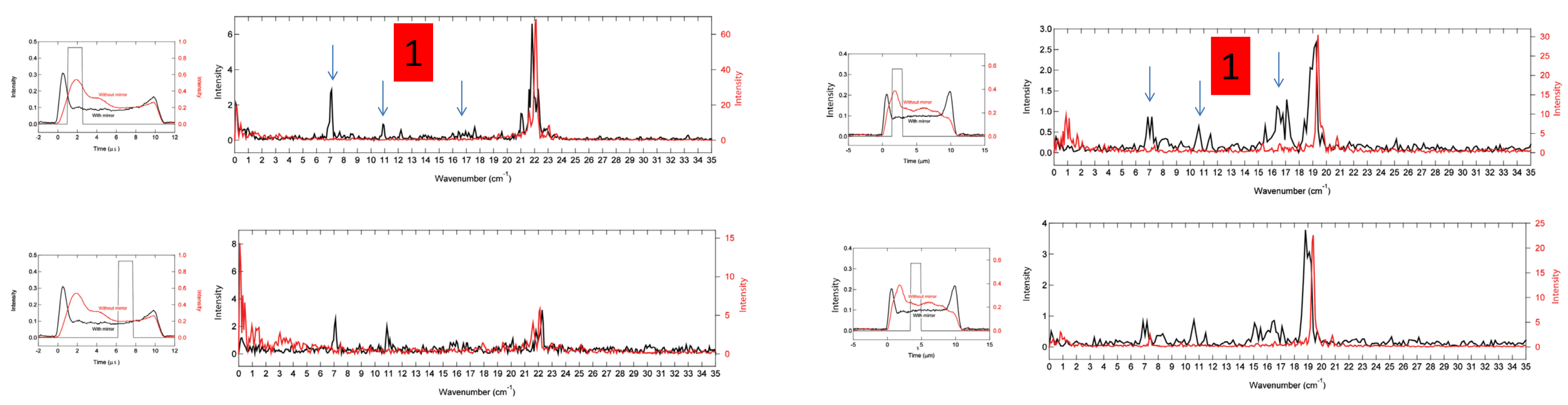


spontaneous emission using 'fast' (1μs) bolometer



spontaneous emission from autocorrelation measurements

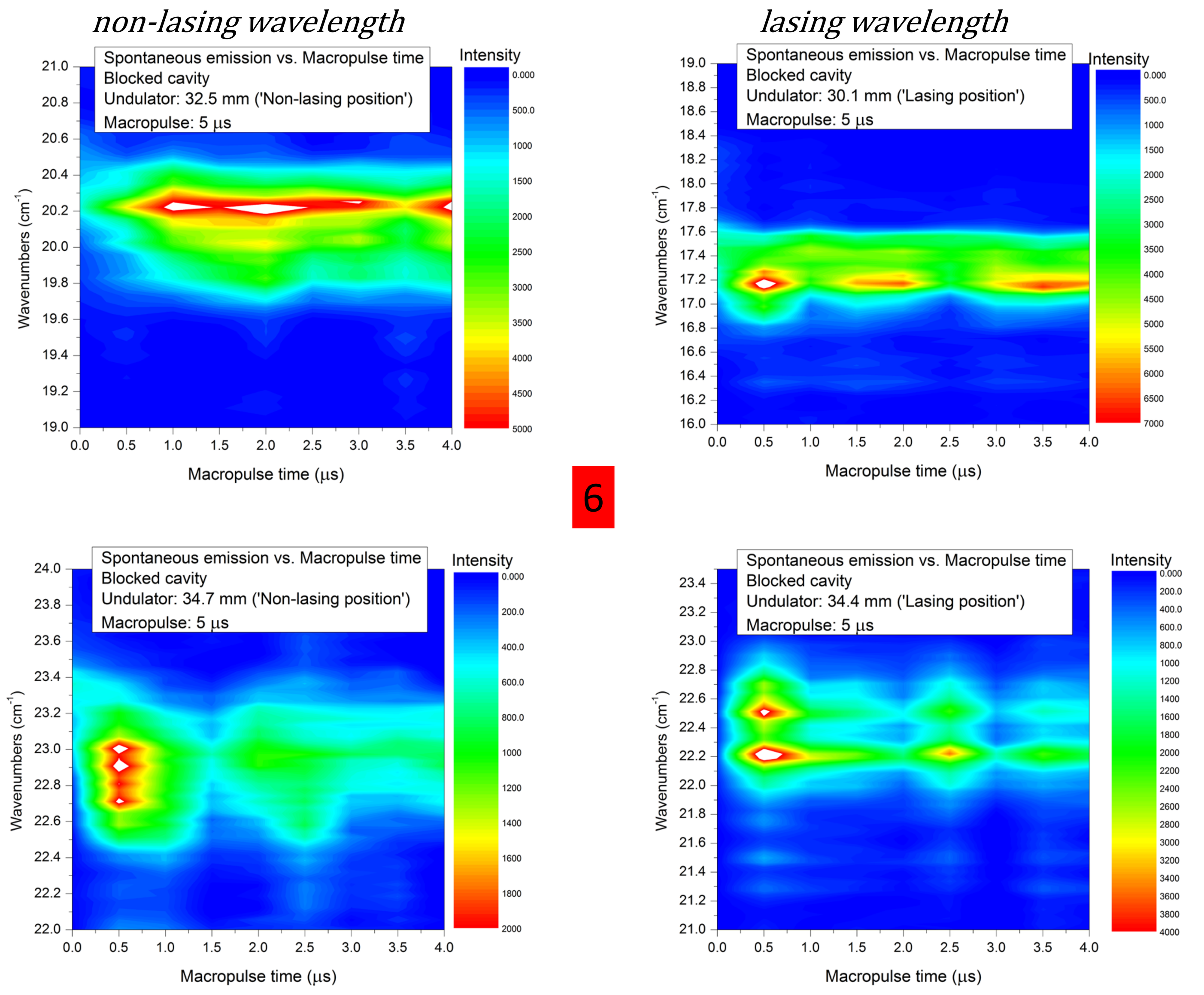
lasing wavelength *non-lasing wavelength*



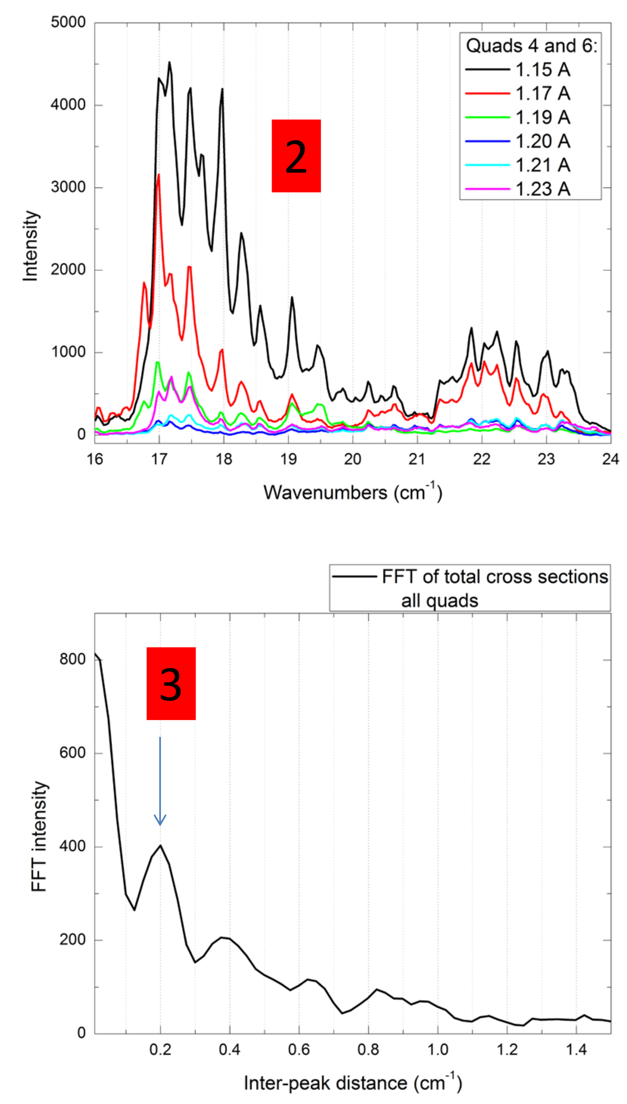
spontaneous emission using sideband generation in ZnTe and a 10 ns dye laser

blocked cavity : *time evolution*

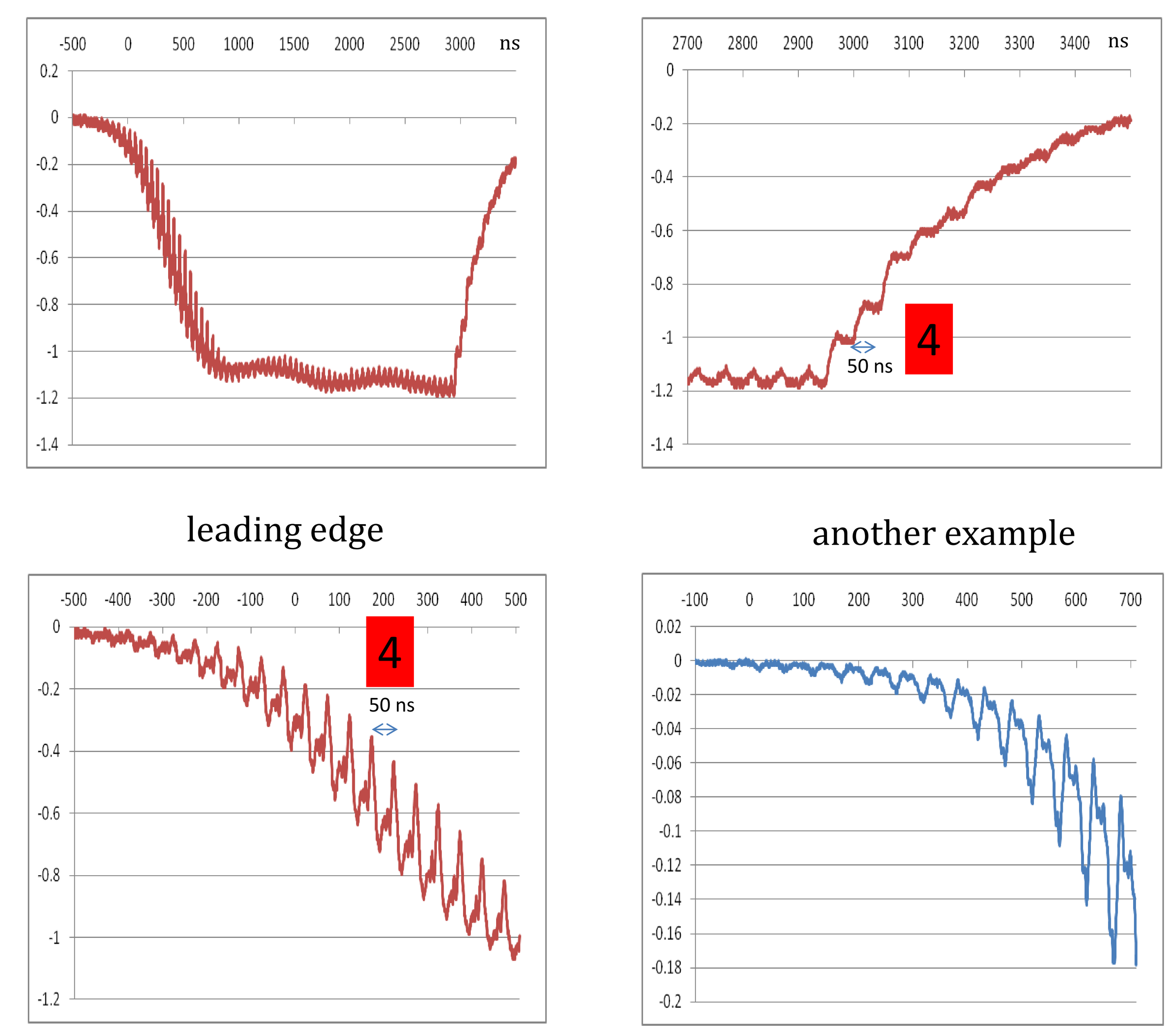
non-lasing wavelength *lasing wavelength*



spectral dependence

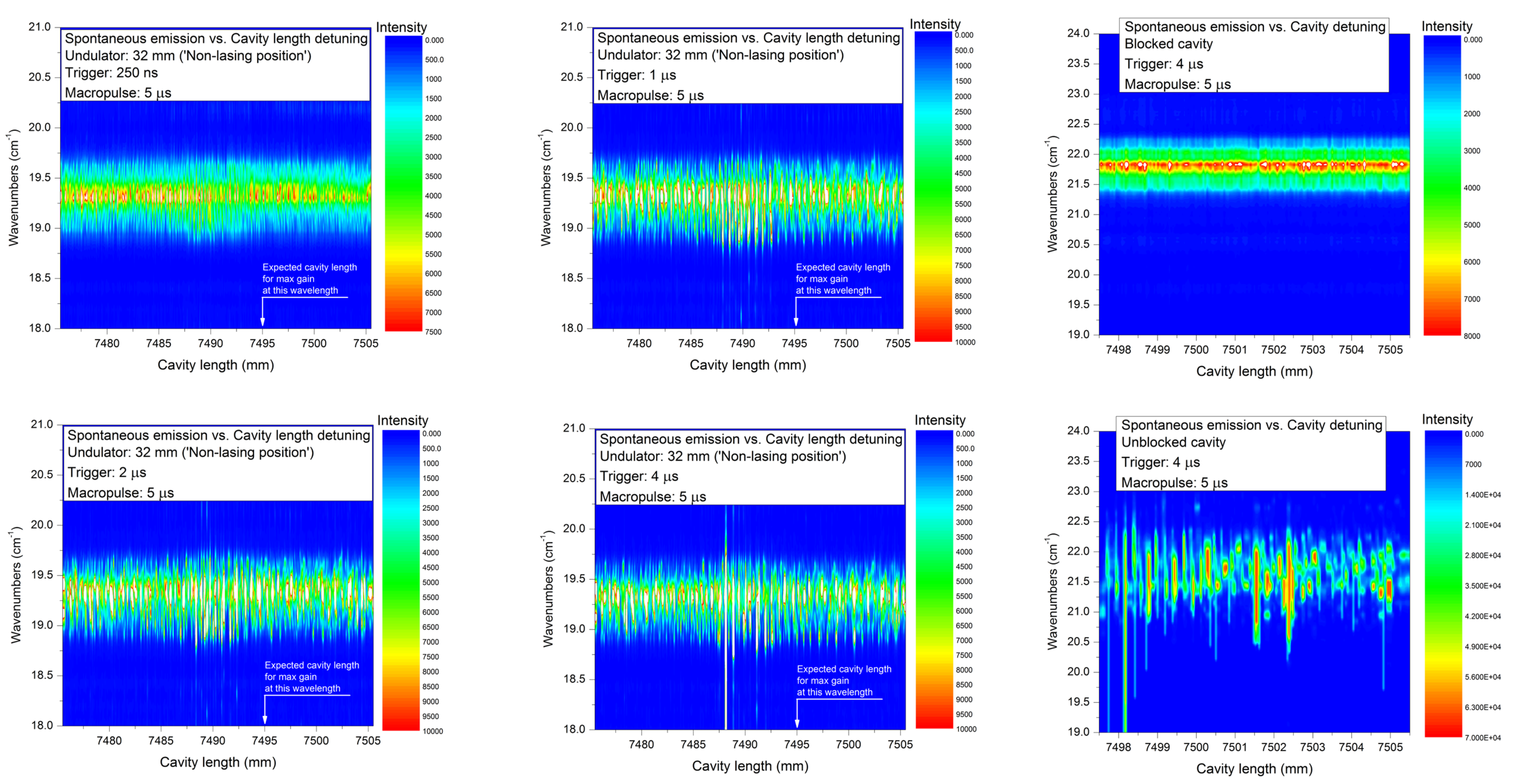


power oscillations at the cavity roundtrip frequency



as a function of cavity length (derived from lasing positions)

non-lasing wavelength 5 *lasing wavelength*



Main observations:

1. Appearance of as yet unexplained low-frequency peaks in spontaneous emission spectra due to cavity
2. Spontaneous emission power 10^{-5} – 10^{-2} of laser power, depending on small changes in beam optics
3. Modulation in intensity of spontaneous emission at 0.2 cm^{-1} rather than at 0.1 cm^{-1}, the inverse of the interpulse distance at 3 GHz
4. Strong oscillations of laser power at cavity roundtrip frequency (50 MHz)
5. Synchronous cavity lengths deviate from values calculated for the expected modes
6. No obvious difference in spontaneous emission at tuning gaps as compared to lasing wavelengths
7. No obvious change in tuning gaps when reducing the micropuls rep. rate to 20 MHz (*preliminary, not shown*)

Any suggestions ?

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