Superlinear Current Dependence in a Grating-Based THz Source:

an open mystery

Heather Andrews
Vanderbilt University
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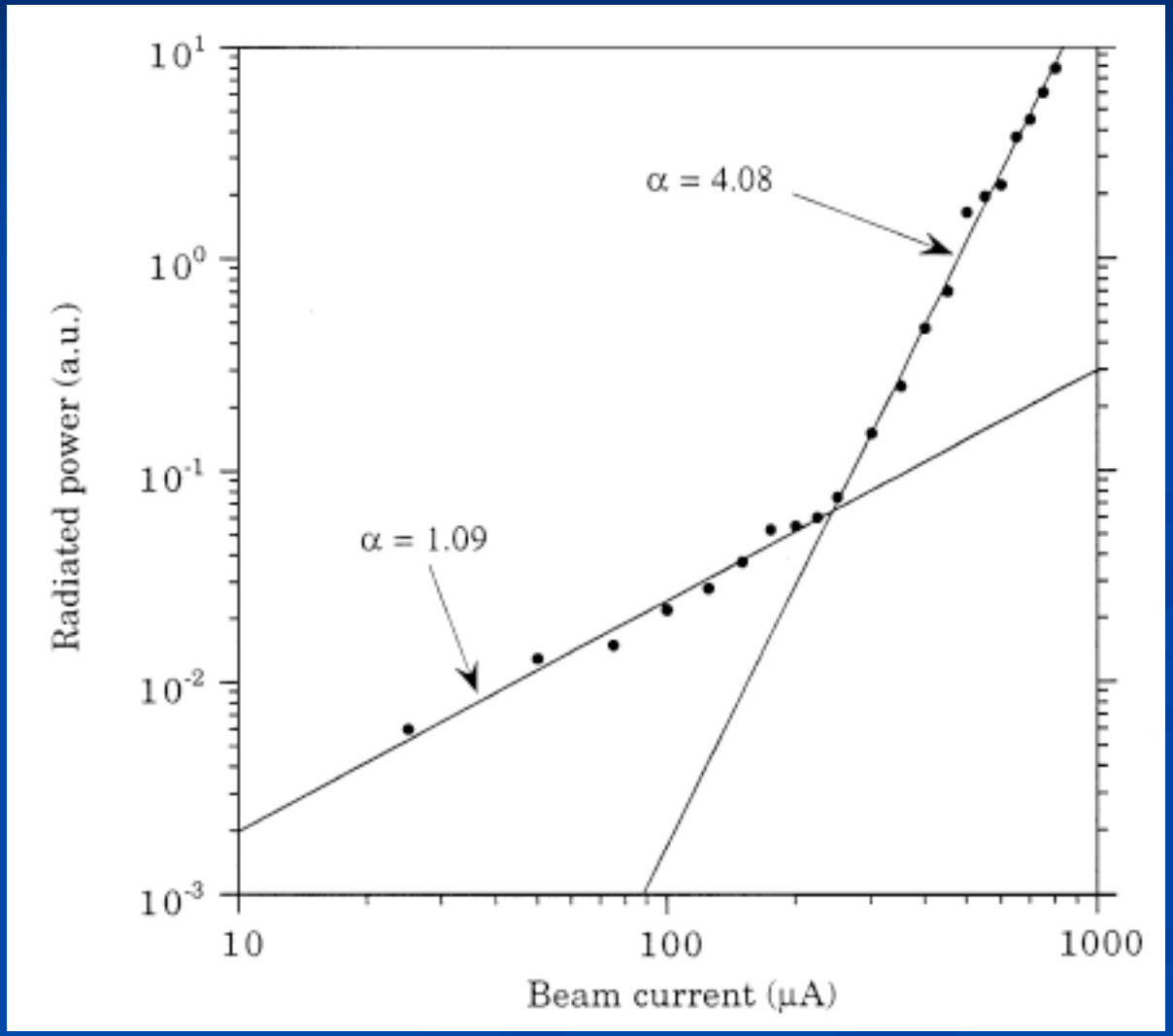
Vermont Photonics: Christian Guertin, Aiden O'Donnell, Mike Mross, Thomas Lowell, Robert Durant

Dartmouth results show superlinear dependence of emission with current

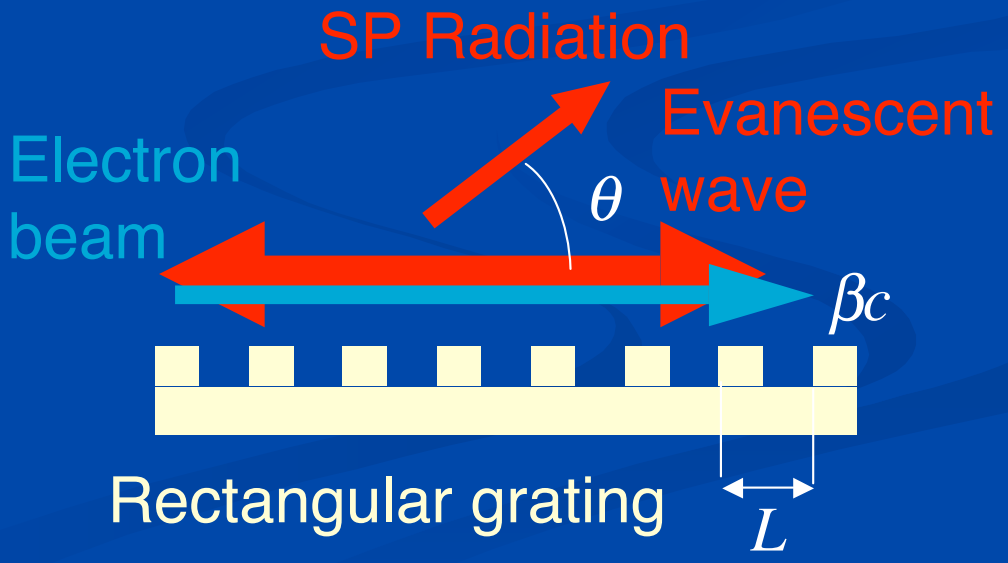


Urata et. al., NIMA 429, 457 (1999)

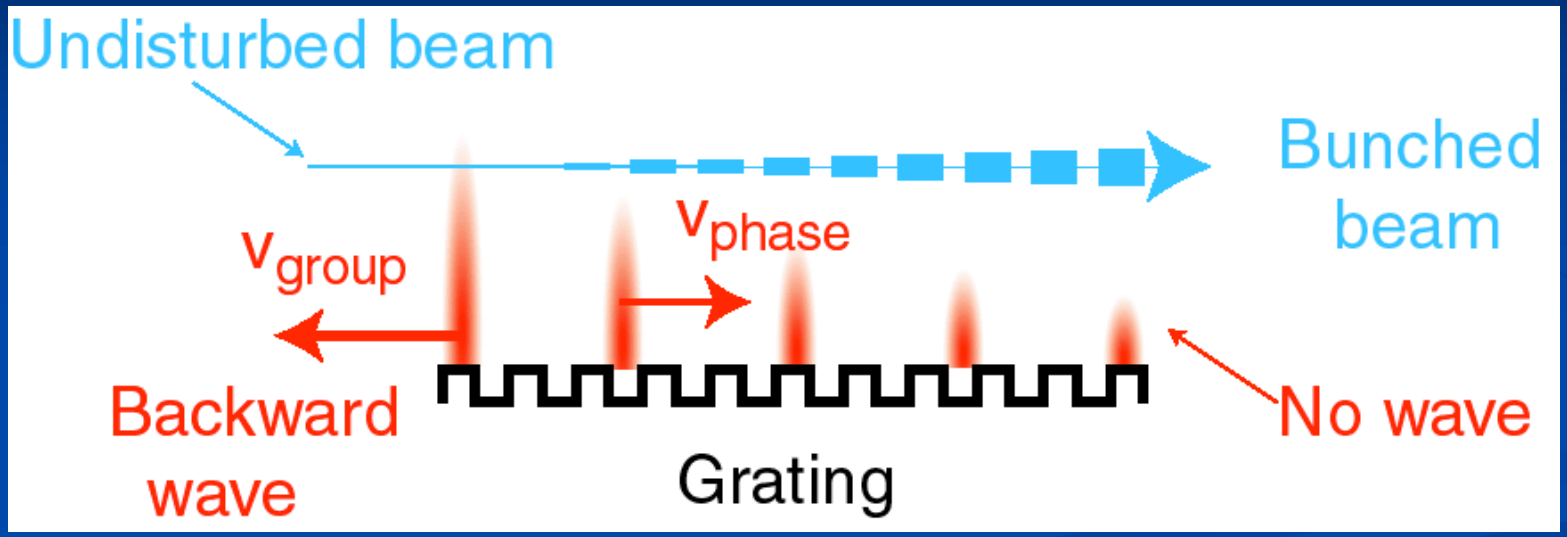
An electron passing over a metal grating produces Smith-Purcell radiation and an evanescent wave

- Smith-Purcell radiation
  - radiates
  - wavelength and angle coupled by Smith-Purcell relation
- Evanescent wave
  - does not radiate
  - scatters off ends of grating
  - has wavelength longer than SP radiation

$$\lambda = \frac{L}{|n|}\left(\frac{1}{\beta} - \cos\theta\right)$$

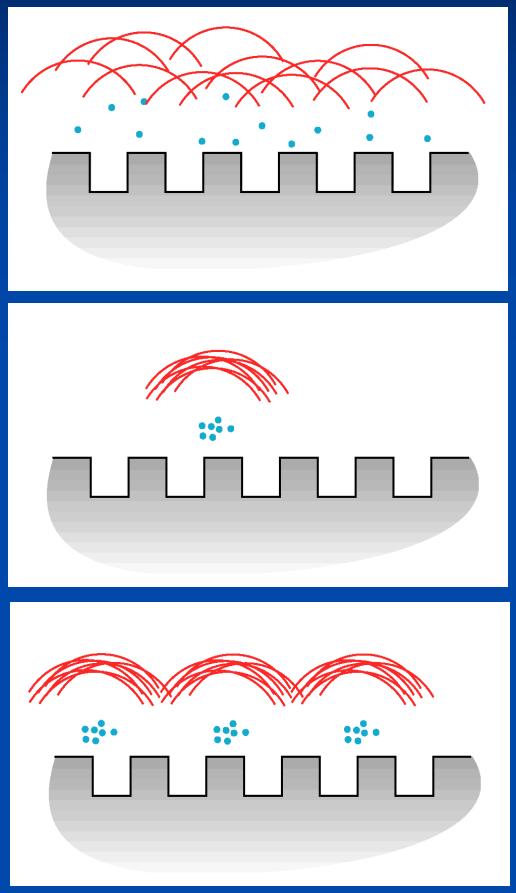


Evanescent wave is key to SP-FEL operation

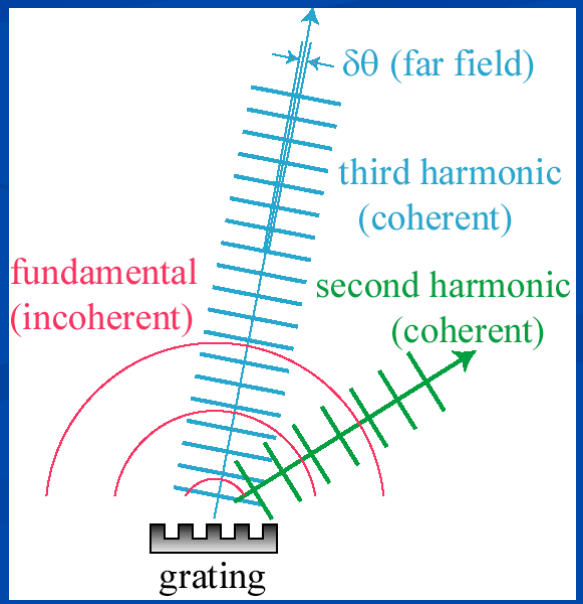


- Evanescent wave
  - Travels opposite to electron beam
  - Provides feedback
  - Bunches beam
- Spontaneous oscillation occurs for e-beam current above “start current”
- Below start current spontaneous SP dominates

Bunching makes SP radiation superradiant

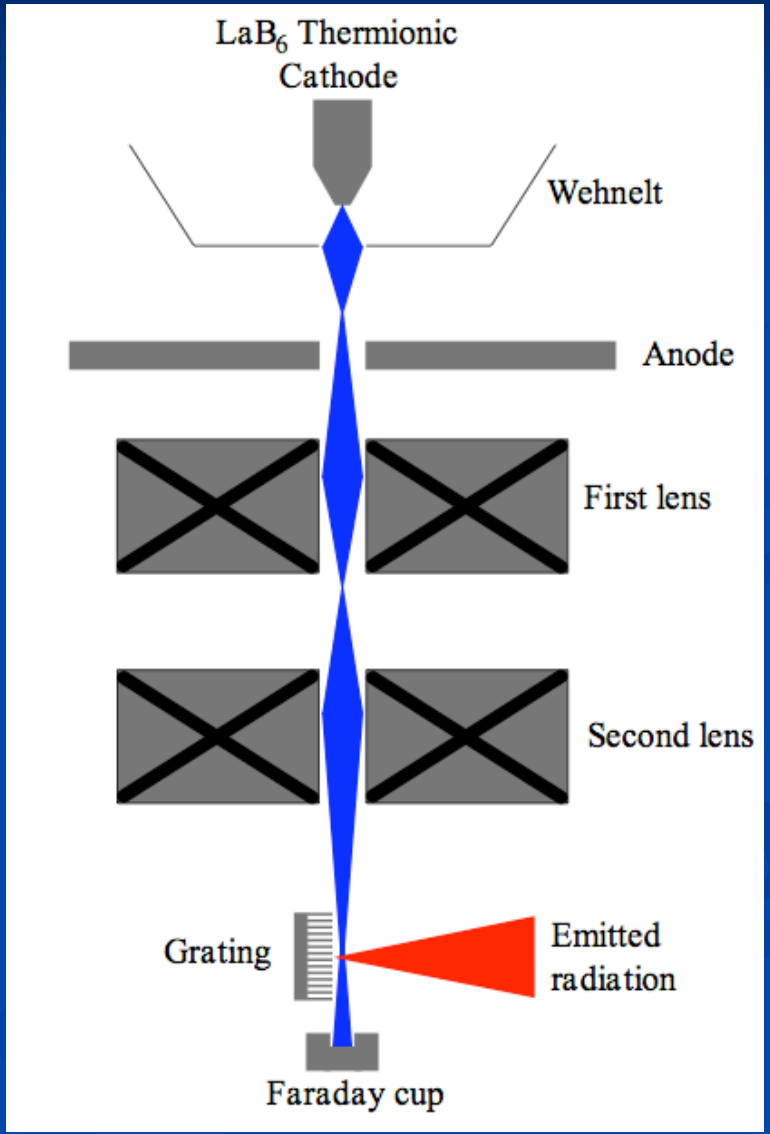


- No bunches:
  - Incoherent emission
  - Intensity ~ N_e
  - Normal SP spectrum
- Single bunch:
  - Coherent emission
  - Intensity ~ N_e^2
  - Spectrum unchanged
- Periodic bunches:
  - Superradiant emission
  - Intensity ~ N_e^2
  - Spectrum peaked at harmonics

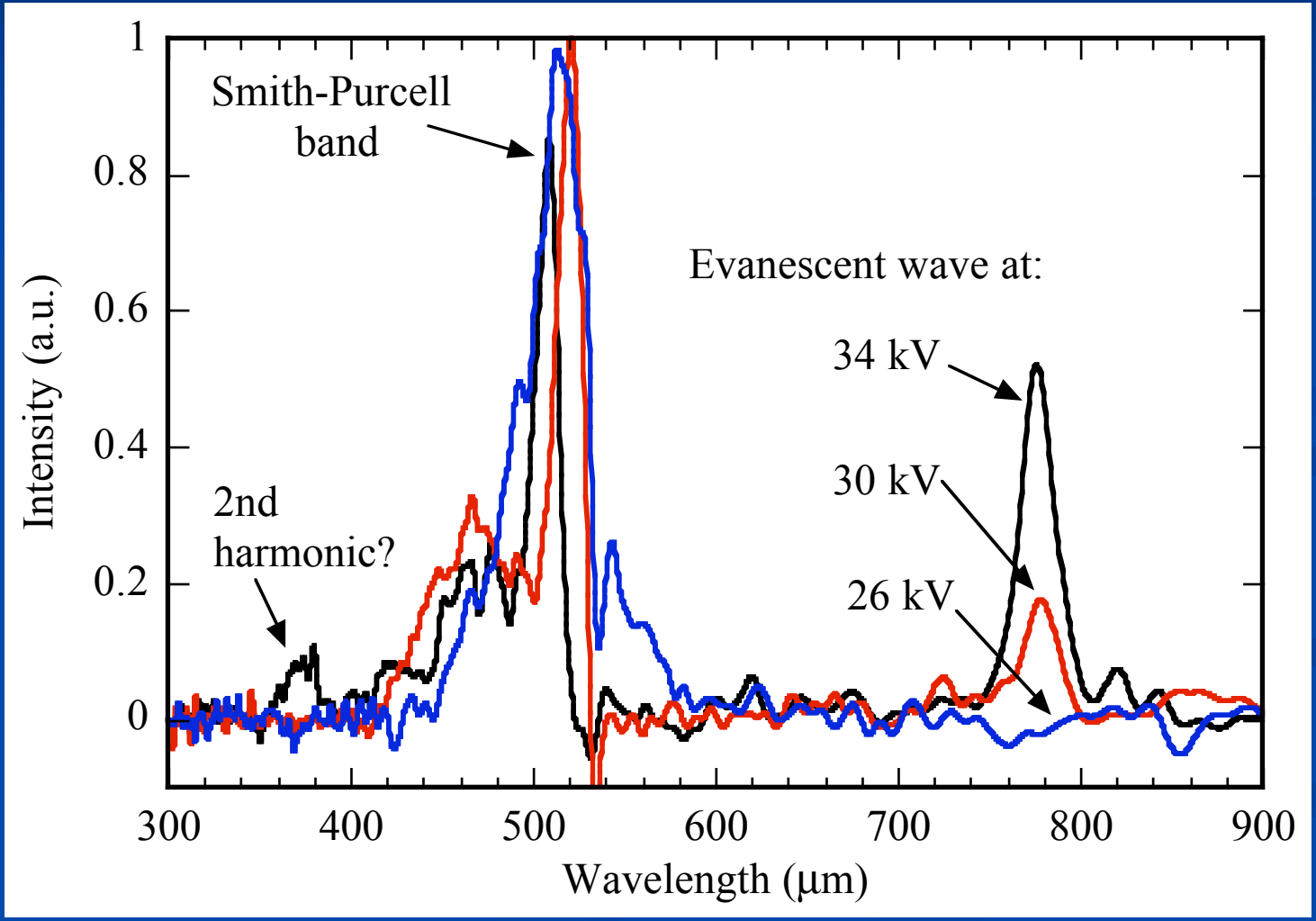


Vermont Photonics THz source based on modified SEM

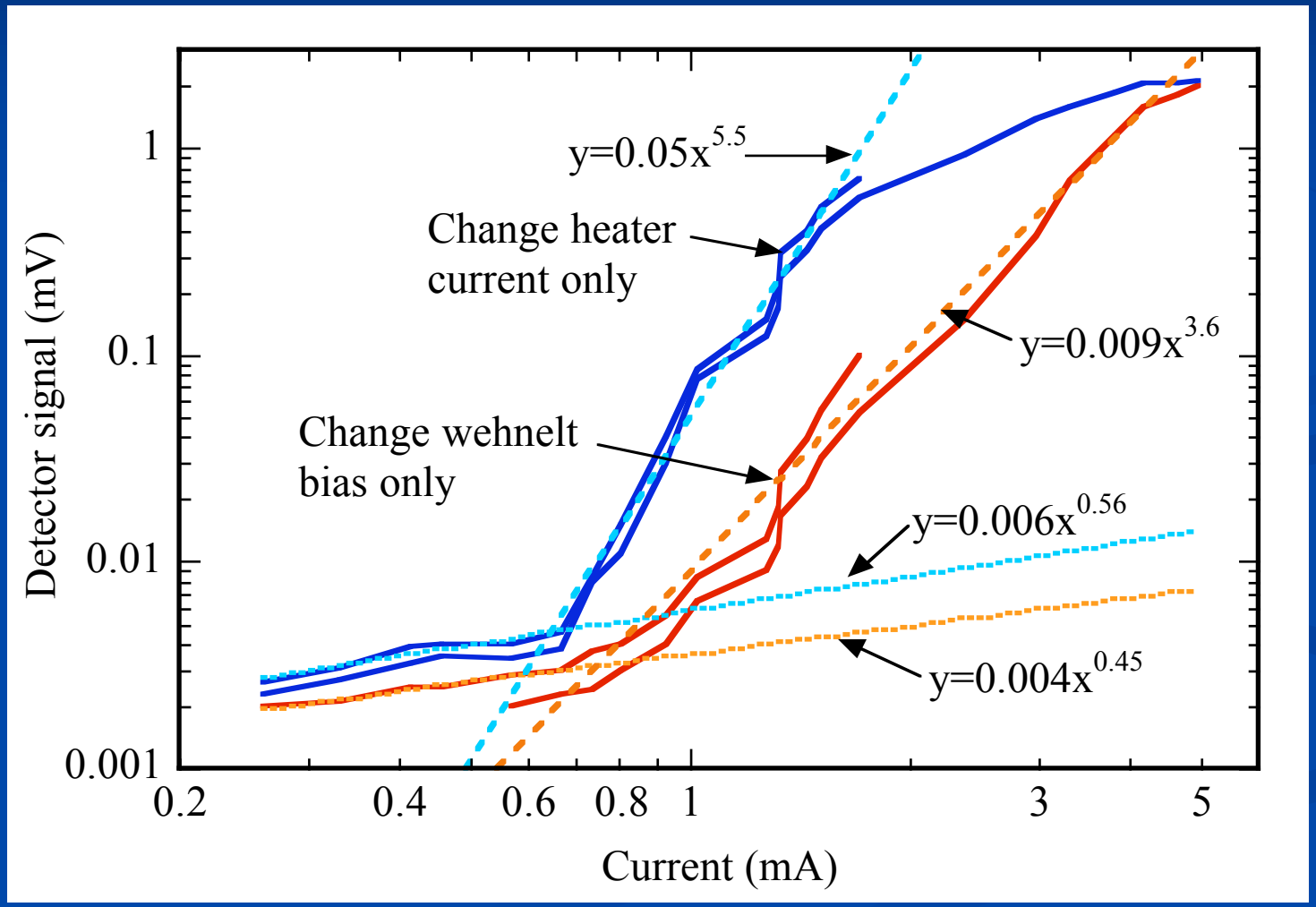
- 26 - 38 kV
- 0.1 - 17 mA
- Current controlled by either cathode heater, or by Wehnelt (or extractor) potential
- Steering coils not shown



We observed the evanescent wave, and possibly the second harmonic



Spontaneous radiation still exhibits superlinear current dependence



Additional clues suggest an electron beam oscillation

- Spectra do not change over range of current

- “Turn on” current is always around 0.5 - 1.5 mA
- Behavior is independent of grating profile, wehnelt shape, cathode, anode-cathode spacing, etc.
- Emitted power is very sensitive to combination of heater current and wehnelt bias and lens setting

We have limited options for testing for bunching

- Because the spectrum is unchanged, bunching must be lower frequency than resolution of spectrometer (6 GHz)
- Enhancement would be at a very high harmonic of bunching frequency
  - Could use a high resolution spectrometer

- Calculations show OTR should be too weak to detect
- Anything placed in the beam path melts
  - Could use loop antenna or Rogowsky coil

Conclusions - An explanation for superlinear power increase is still lacking

- Superlinear power dependence on current is observed for two sets of grating FEL experiments
- The existing theory does not explain this behavior
- Some type of cathode oscillation or beam bunching could explain behavior

Ideas are welcome!