Investigation of Coherent Emission from the NSLS VUV Ring

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NSLS VUV ring

- 0.808 GeV
- 52.88 MHz main rf cavity
- 9 rf buckets
- up to 400 ma in a single bunch
- bunch lengths from ~100 ps to 2 ns
- Chasman-Green lattice, 4 super periods.
- nominal momentum compaction α_0 ($\cong \eta$) = 0.0235

Multiparticle Coherent Emission

Synchrotron emission by a single electron

$$P(\omega) \equiv \frac{d^2 I}{d\omega d\Omega}_{\text{one particle}} = \frac{e^2\omega^2}{4\pi^2 c}\left|\int_{-\infty}^{\infty} \hat{n}\times\left(\hat{n}\times\vec{\beta}\right)e^{i\omega[t-\hat{n}\cdot\vec{r}/c]}dt\right|^2$$

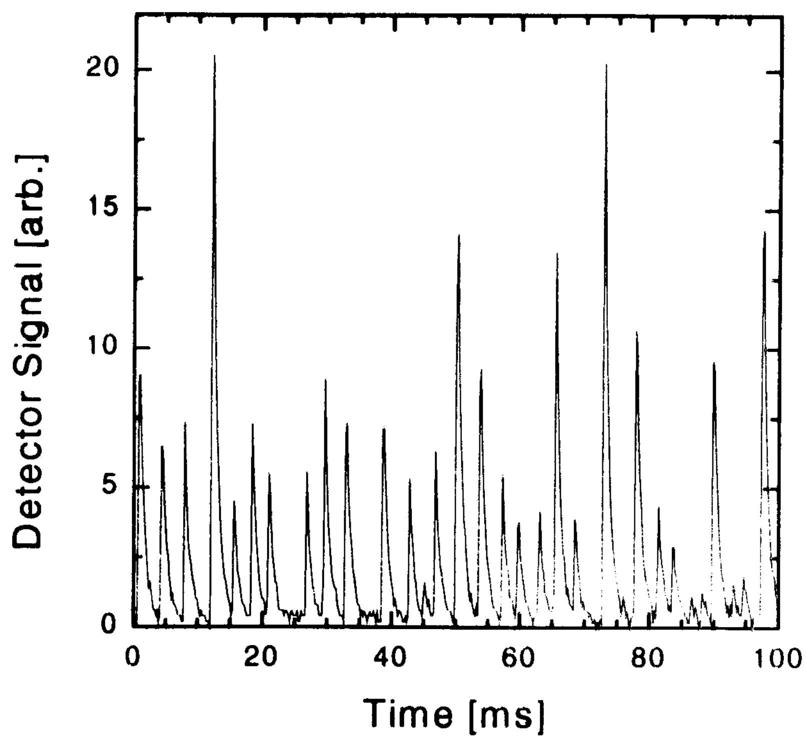
For multiple electrons (Nodvick & Saxon, Williams et al., Hirschmugl et al.)

$$\frac{d^2 I}{d\omega d\Omega}_{\text{multiparticle}} = \left[N + N(N-1)f(\omega)\right]P(\omega)$$

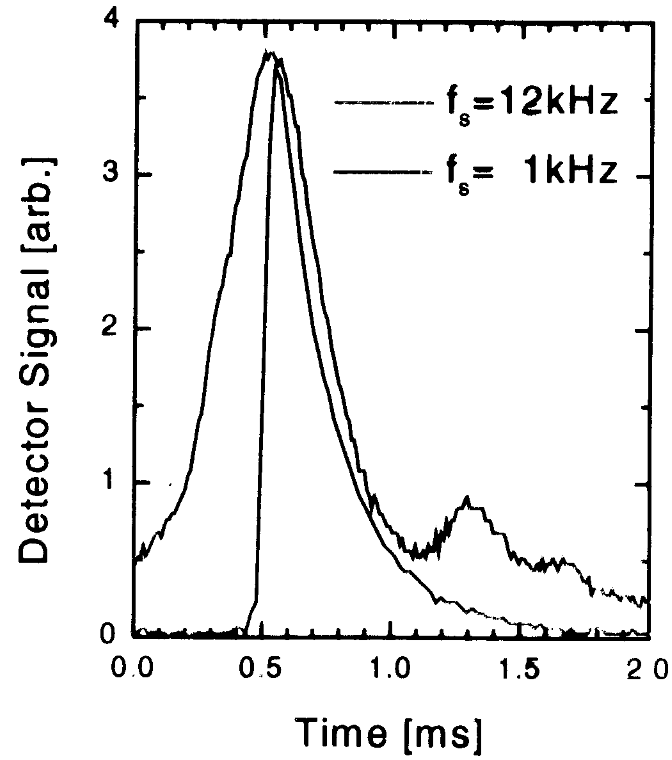
where $$f(\omega) = \left|\int_{-\infty}^{\infty} e^{i\omega\hat{n}\cdot\vec{r}/c} S(r)dr\right|^2$$

Emission bursts

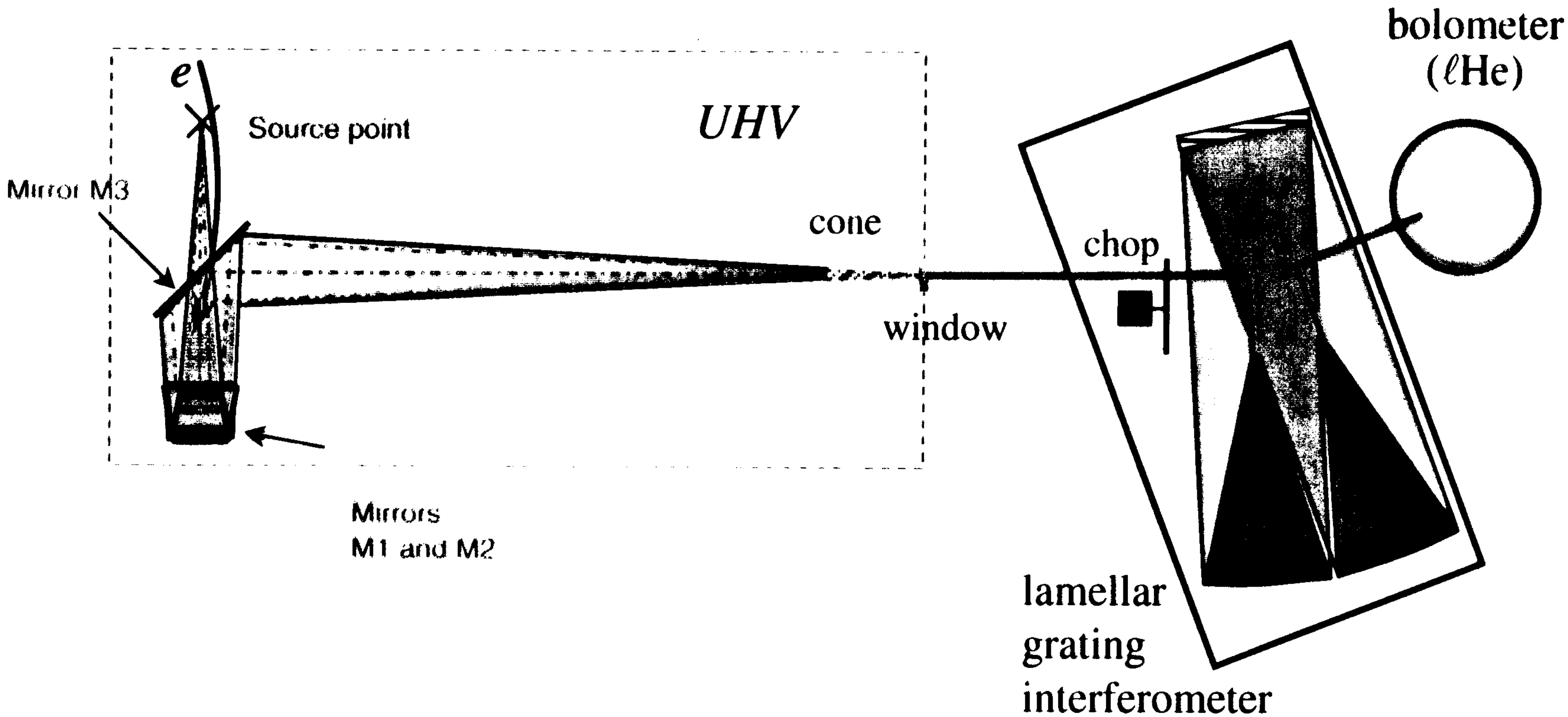
- *Quasi-periodic bursts*
- *T ~ 1 to 10 ms*
- *detector-limited fall time*



- *Duration < 100 μs for $\alpha = \alpha_o$*
- *increases with decreasing α*

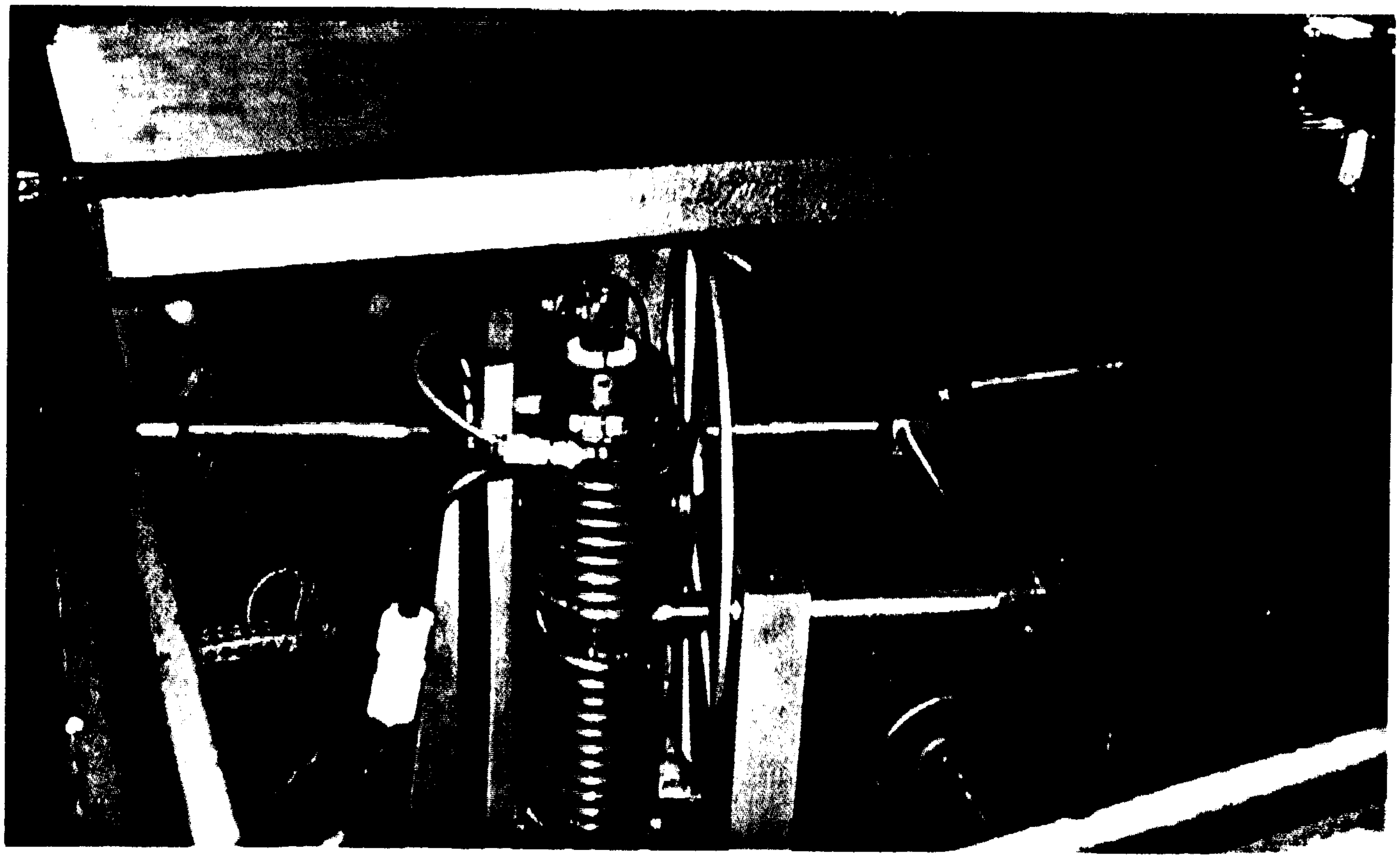


U12IR - beamline / spectrometer

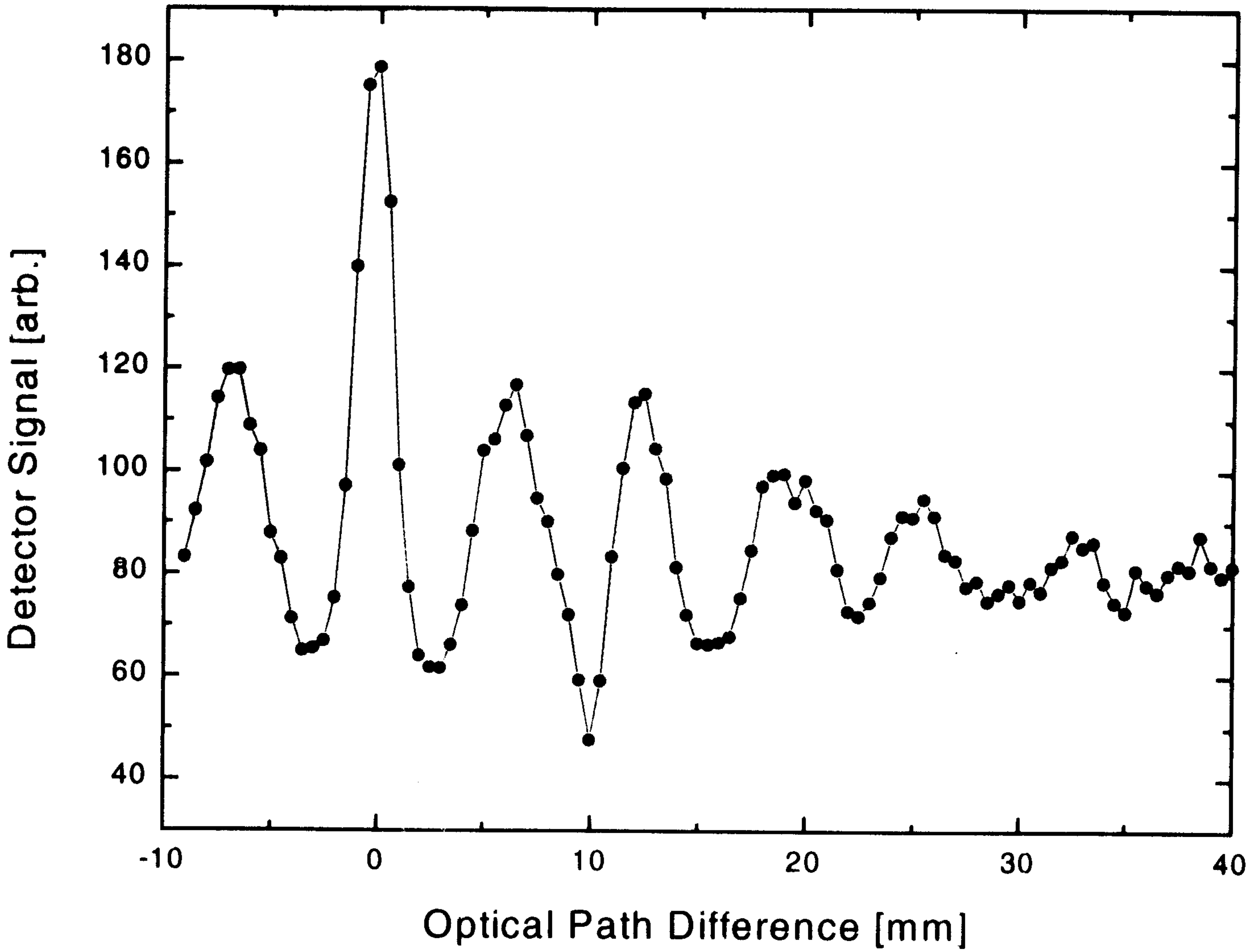


U12IR Spectrometers

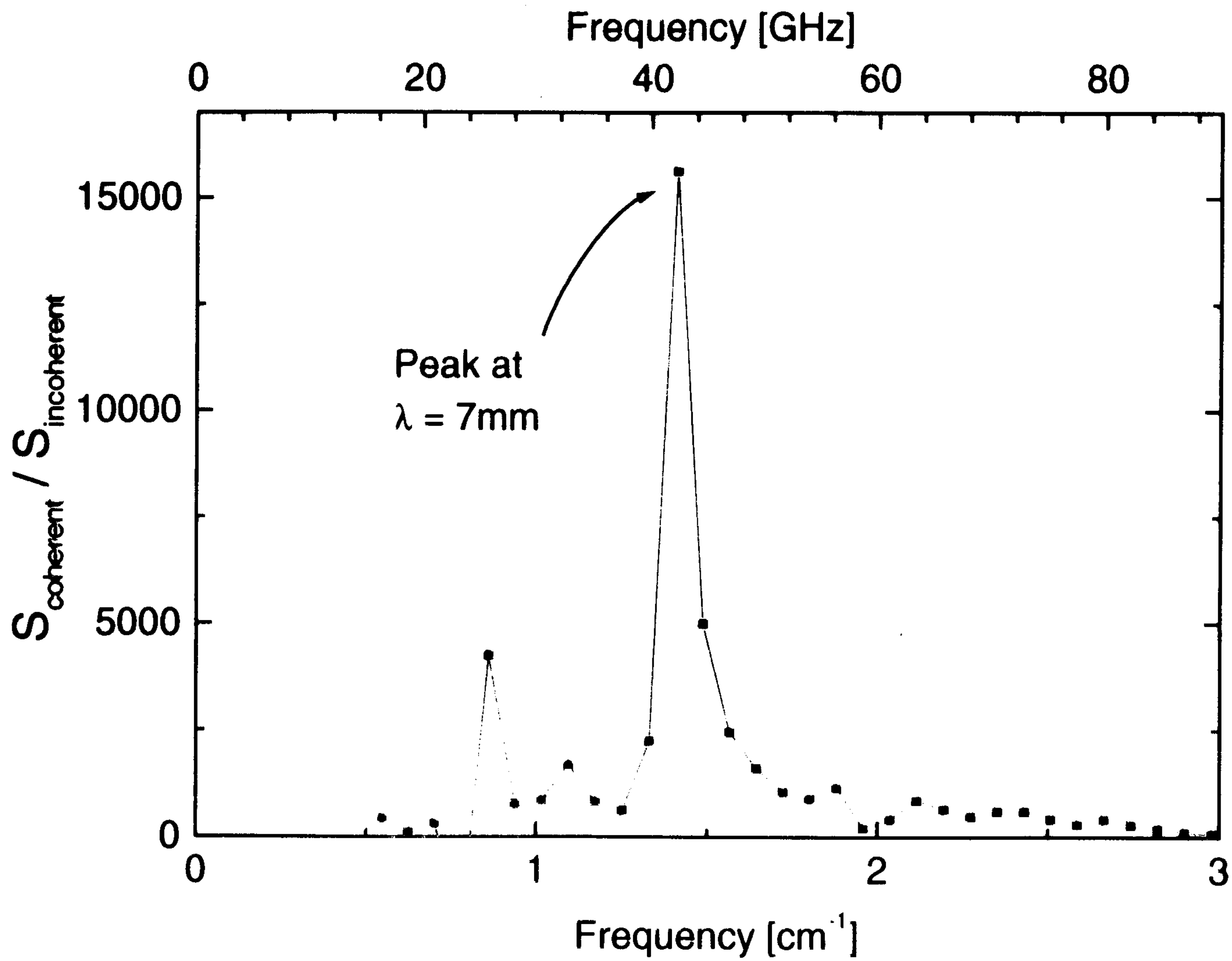
- <u>lamellar grating (wavefront dividing) interferometer</u>
  - spectral range from 1 cm^{-1} to 100 cm^{-1} (30 GHz to 3 THz), 0.25 cm^{-1} res'n.
  - "light pipe" and mirror optics, thermal IR detector (bolometer)



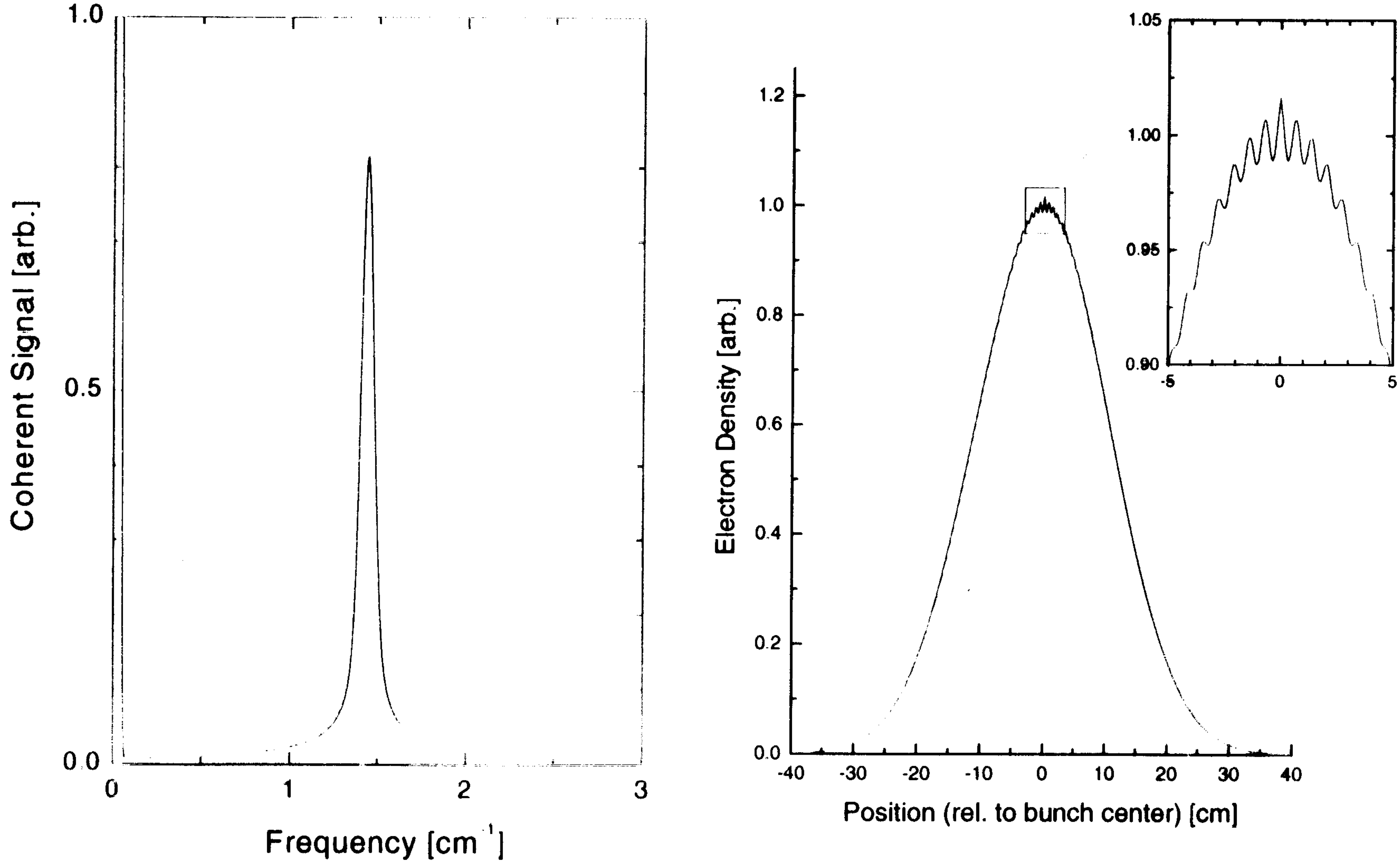
Interferogram



Spectroscopic analysis

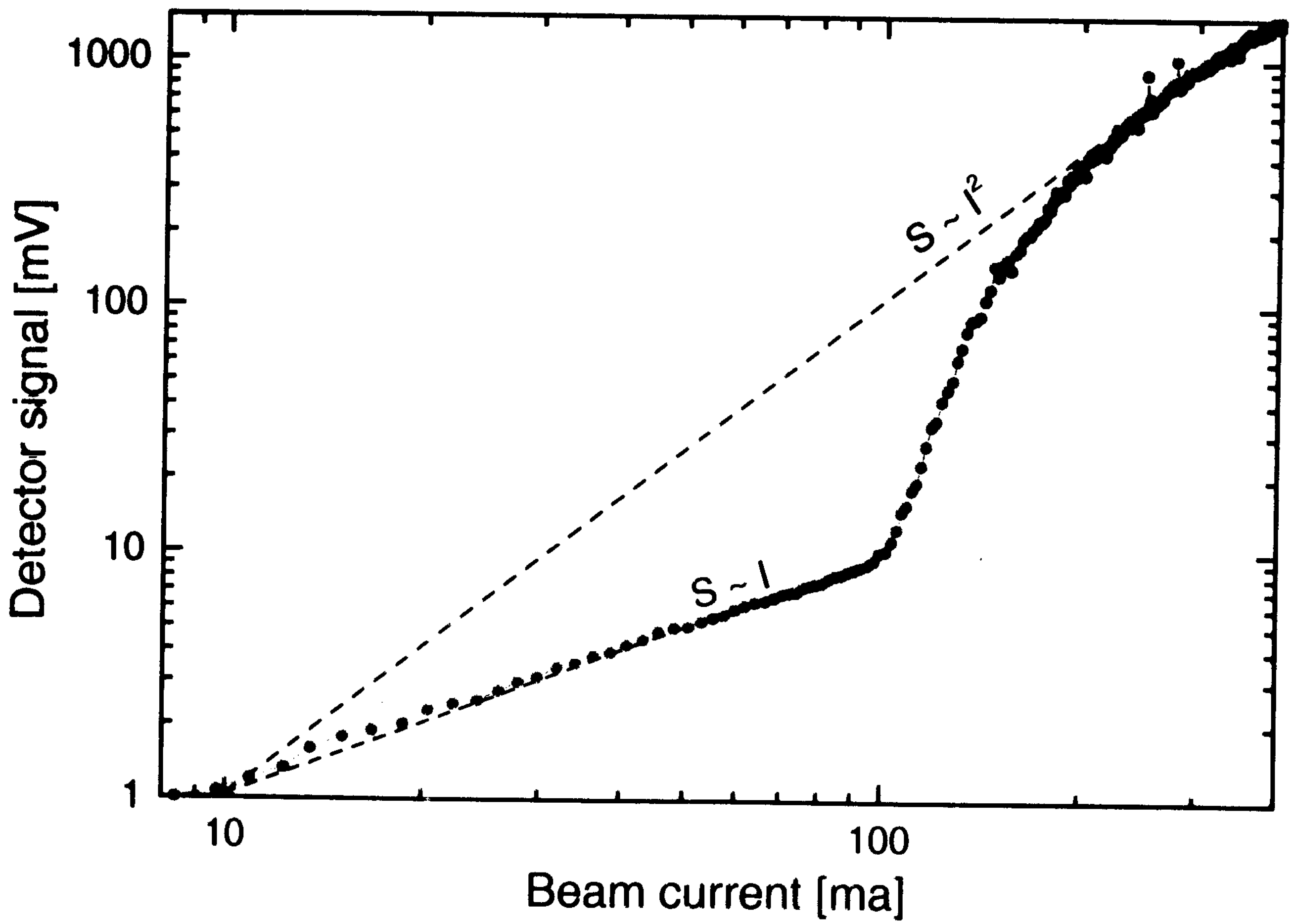


Density modulation



Beam current dependence

- I^2 dependence beyond threshold.
- threshold depends on operating parameters (E, bunch length, α).



Threshold dependence on f_{s0}

Keil-Schnell

(coasting / unbunched beam)

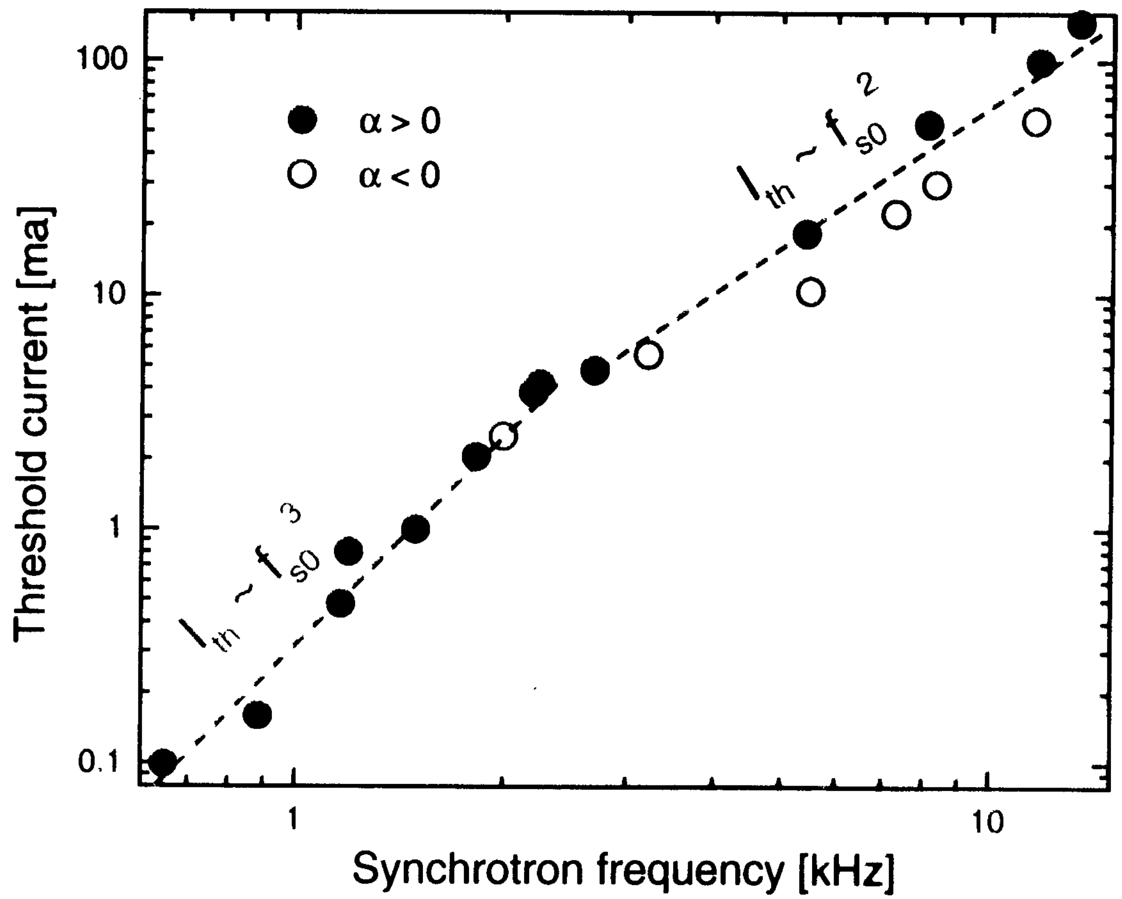
$$eI_{ave} \frac{Z_n}{n} \leq 2\pi\alpha E\sigma_E^2$$

$$\Rightarrow \quad I_{th} \propto \alpha \sim f_{s0}^2$$

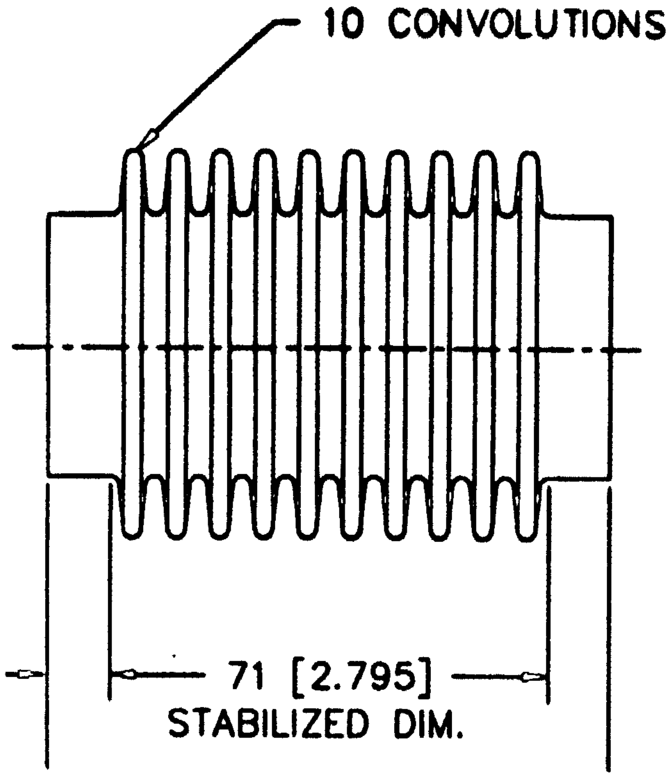
Boussard

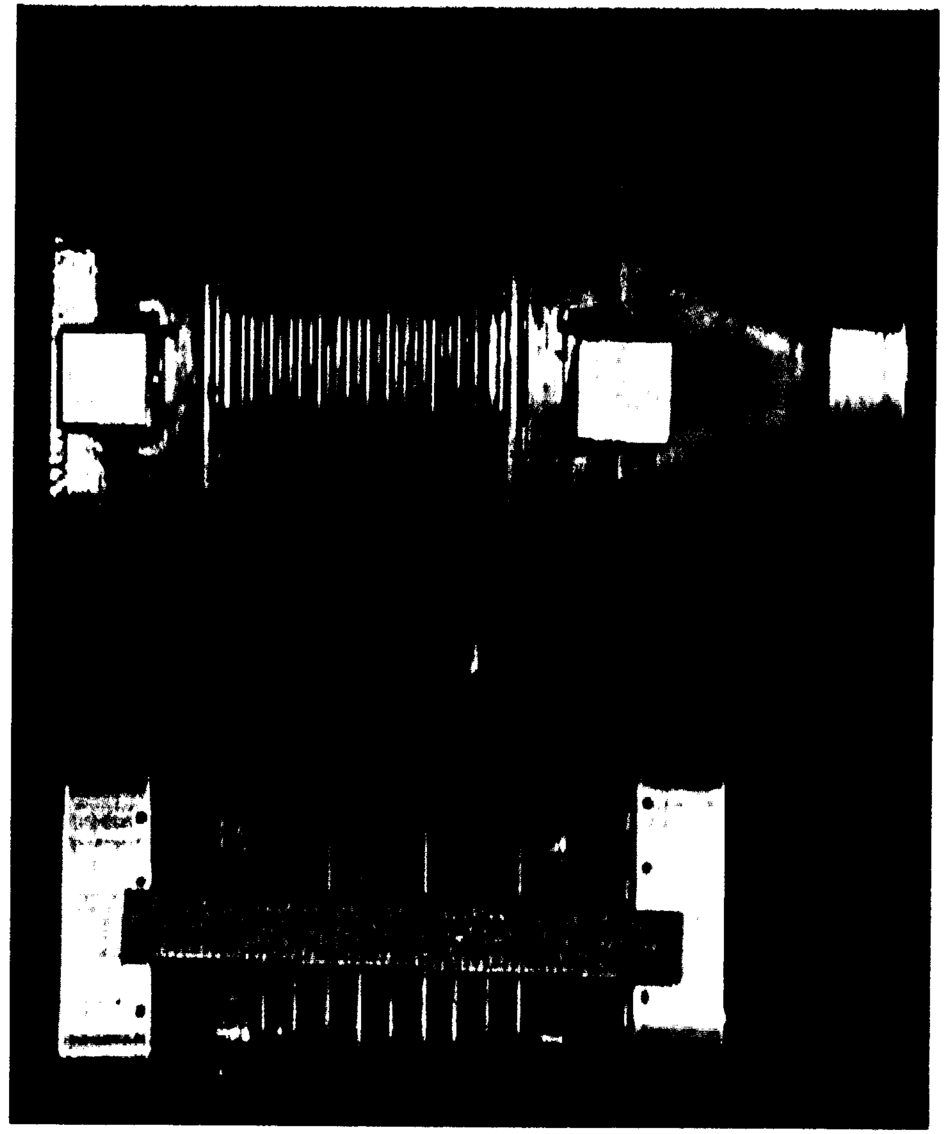
replace I_{ave} with I_{peak}

$$\Rightarrow \quad I_{th} \propto \alpha^{3/2} \sim f_{s0}^3$$



Electron beam vacuum/RF bellows





Summary

- Observe enhanced emission from NSLS VUV ring at 7 mm wavelength.
- Emission occurs after a current threshold I_{th} is exceeded, grows as $(I - I_{th})^2$.
- Emission is not continuous, but occurs in quasi-periodic bursts.
  (similar to SURF and storage ring FEL oscillations observed at SuperACO).
  - period ~ 1 to 10 ms; rise/fall times faster than synchrotron damping time.
- I_{th} varies linearly (quadratically) with α (f_{s0}).
- 7 mm emission, narrower(?) than spectrometer resolution limit of 0.25 cm^{-1}.
- Data below 30 GHz (1 cm^{-1}) is lacking.
- Microwave instability? *(J.-M. Wang, Phys. Rev. E '98).*

Acknowledgements: J-M Wang, N. Towne, G.P. Williams, S. Krinsky