STOCHASTIC COOLING @ COOL03

- Why consider s.c. at rhic?
  - Debunched beam
  - Future
- Will it work?
  - Schottky signals
  - Coherence
  - Proton BTF/solitons
- How to do it?
  - Frequency range
  - Palmer cooling
  - Filters

- How much will it cost?
  - Microwave power is expensive, 10 kW > 2M$
  - Kicker impedance
  - Pulse expansion/compression
- Future
  - Expand to transverse plane
  - Complement e-cooling/collect the tails

The Problem

- IBS
  - Emittance growth drives beam out of the bucket
    - Diminishes effective luminosity
    - Creates de-bunched beam, > dirty dumps
  - Can't FIX the problem (atomic scale)
    - Mitigate with bigger buckets (momentum aperture)
    - Emittance blowup strategies
    - Gap cleaning
  - Not a surprise
- Cooling can counteract IBS
  - So why wasn't cooling part of the original project scope?

RHIC Design Manual

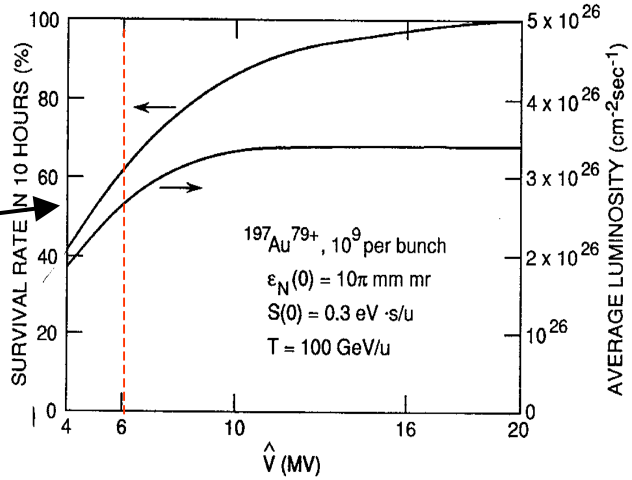
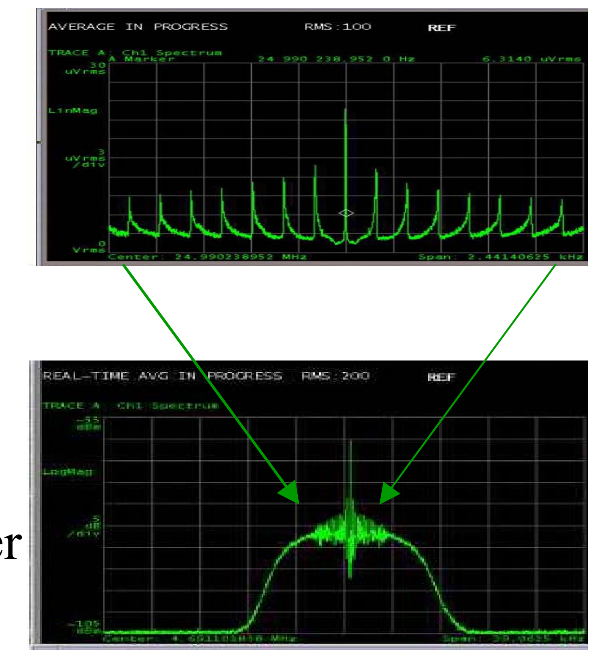


Fig. 7-3. Dependence of final beam survival rate and average luminosity on storage rf voltage after 10-hour operation, "constant voltage" scenario (courtesy J. Wei).

Schottky Spectra

- *"if you want to find out if cooling can work look at the Schottky signals"* (consensus of experts)
  - Signal to noise ratio
  - Mixing situation
  - Anomalous coherence

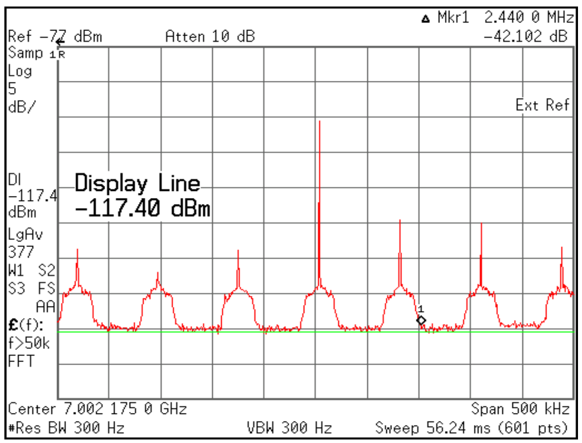


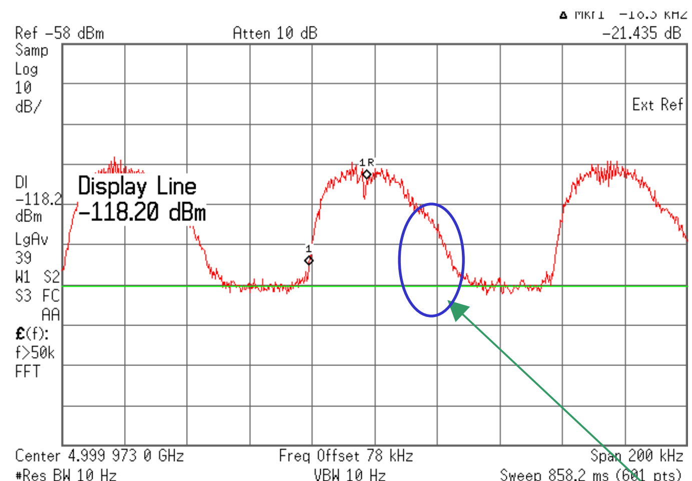
- The signal to noise ratio is high for ions
  - For the same number of charges in the ring the Schottky power from ions is Q times larger than from protons

Schottky signals from 2.7 GHz narrowband pickup. Many synchrotron sidebands are resolved. Signal to noise ration > 25 dB.

Schottky signals in the 4-8 GHz band

- Fermilab loaned to RHIC a pickup and kicker pair at 4-8 GHz
- Looking at the gold beam



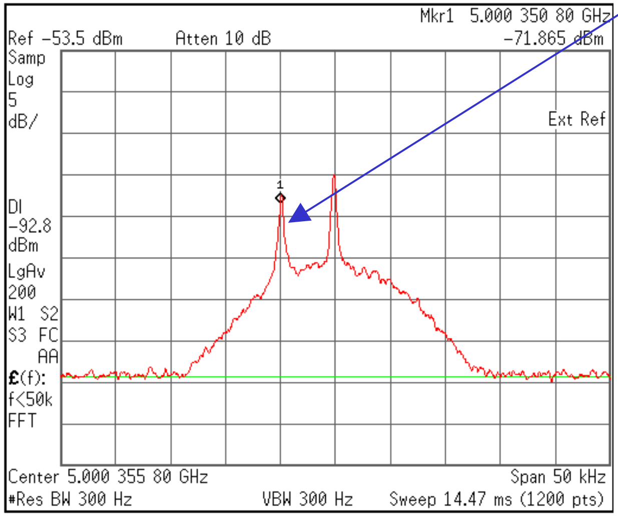


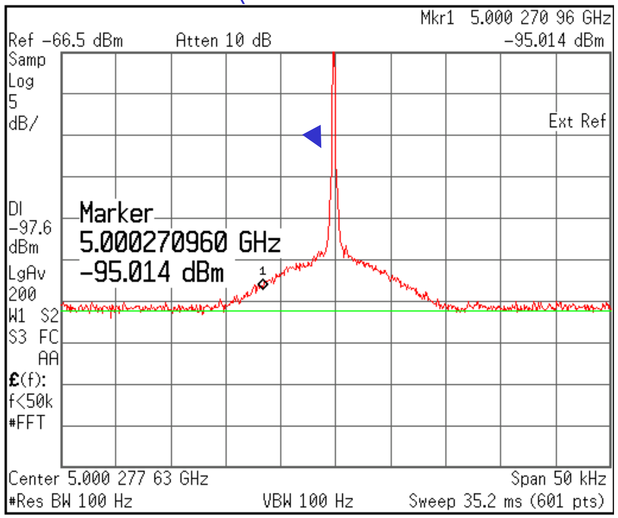
1. At 7 GHz early in a store, via 150 m cable
2. Coherence lines show up at harmonics of the bunch frequency
3. Even at 7 GHz the Schottky bands do not overlap,⇒ poor mixing

1. Late in the store at 5 GHz we see de-bunched beam, coasting on the low-energy side
2. The coherence has dissipated
3. The signal to noise ~ 30 dB

Protons (polarized)

- Looking at the proton beam
- The significant difference in that the coherence lines do not dissipate
- This is consistent with experience at TEVATRON and SPS
- We also measured the longitudinal Beam Transfer Function by driving the kicker (5 Watts) at a single frequency within the distribution





Longitudinal Beam Transfer Function

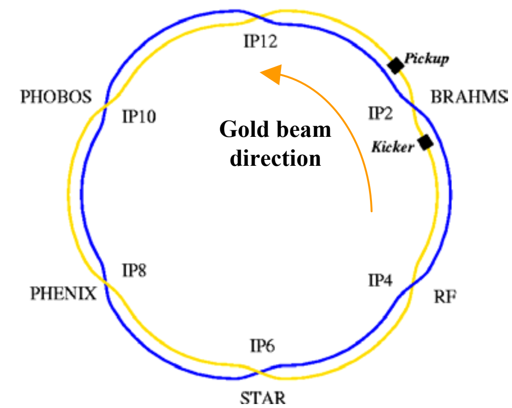
• The beam transfer function represents the beam's response to stimulus of the kicker

• It is a key part of feedback loop of a cooling system

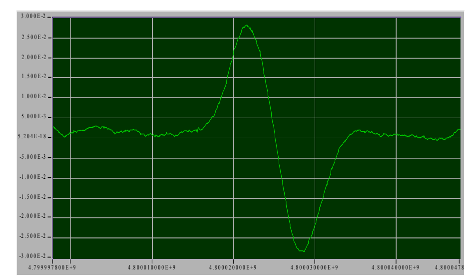
•For a coasting beam it is given by the dispersion integral,

$$B(\omega) \propto j \int \frac{\frac{d\psi_0}{dE}}{\omega - n\omega_0 - nkE} dE$$

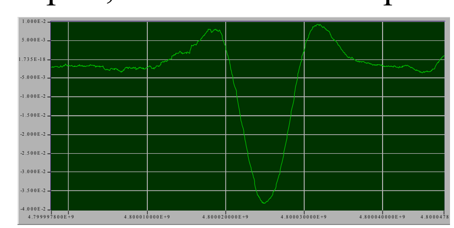
1. **Real part is anti-symmetric and proportional to the derivative of the energy distribution function**
2. **The imaginary part is symmetric and extends beyond the zero of the real part, where the interaction is pure reactive**
3. **The magnitude calibrates the impedance of the pickup and kicker**



Beam Transfer Function, 2×10^{12} protons



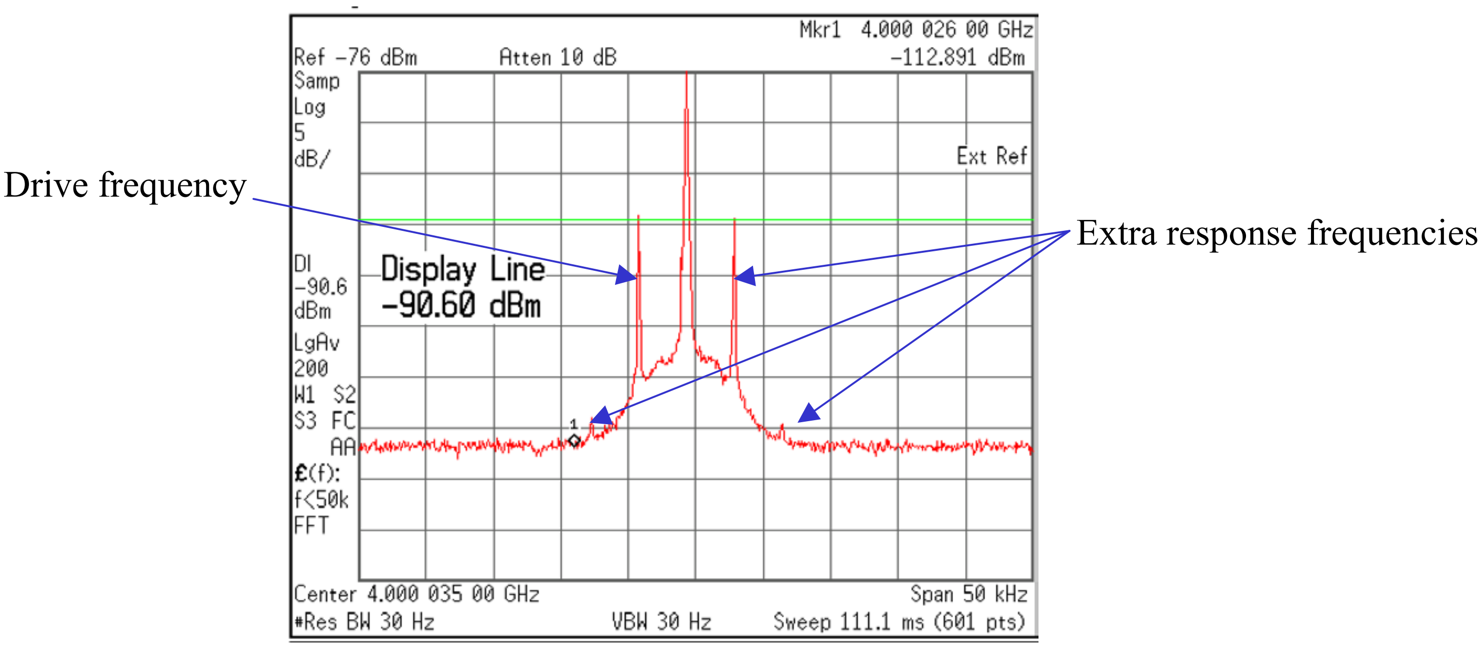
Real part, 5 GHz center frequency



Imaginary part, 50 kHz span

The BTF in not always so straightforward

- Sometimes the response resembles low-frequency bunched beam BTF
- Generating mirror image frequencies at ±Δf, ±2Δf,…
- Indicates creation of some long-lived (>>$\tau_{synchrotron}$) structures, eg: solitons
- This seems to be the key difference between protons and ions



Stochastic Cooling Development Plans

1. Examine Schottky signals…..
2. Measure Beam Transfer Function….
3. Demonstrate some cooling…….FY04
4. Design a practical momentum cooling system
   a. Filter method/Palmer cooling (halo cooling)
   b. Frequency band
      i. 4-8 GHz implies a 2/3 turn delay is OK
      ii. 6-12 GHz better mixing, ½ the cooling time, 1/6 turn delay
   c. Kicker power requirements
      i. 10 kW = 2 M$
      ii. Higher impedance kickers (slotted waveguide) [McGinnis at FNAL]
      iii. Power leveling (pulse expansion/compression) [proposed by F. Caspers]
      iv. Fourier decomposition (only 20 lines are relevant) [proposed by Boussard for SPS]

5. In the long range, when RHIC is equipped with e-cooling, stochastic cooling would be a natural complement
   a. E-cooling works best on a cool beam. It tends to collect beam into a dense core
   b. Stochastic cooling works best on a hot beam. It could capture beam in the tails and contribute to the effective luminosity

Two-Turn delay filter

- Filter emphasizes high momentum deviation particles
- Extends deltaP reach
- Saves power