SLC and the Sawtooth (from grad student's perspective)

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NSLS

Robert H.Siemann Symposium

July 7, 2009

Background

- I graduated from Moscow Inst. of Physics & Technology, MS in Physics, summer of 1993
- I enrolled in Stanford Ph.D. program in Appl. Phys., fall 1993
- I knew nothing about accelerators or acc. physics
- In October 1993 I met Bob Siemann …

Professor

AP 324: Introduction to Accelerator Physics

Boris Podobedov

AP 324. Problem set 4.

13/15

1. Smooth approximation

$$\beta = \frac{R}{Q} = \frac{C}{2\pi Q} = \begin{cases} 0{,}67\ \text{m} & (H) \\ 1{,}74\ \text{m} & (V) \end{cases}$$

4/5

$$\eta = \frac{R}{Q^2} = \begin{cases} 8{,}08 \cdot 10^{-2}\ \text{m} & (H) \\ \cancel{0{,}84\ \text{m}} & (V) \end{cases}$$

$$\alpha = \frac{\eta}{R} = \frac{1}{Q^2} = \begin{cases} 1{,}45 \cdot 10^{-2} & (H) \\ \cancel{9{,}7 \cdot 10^{-2}} & (V) \end{cases}$$

There is no dispersion or momentum compaction in the vertical plane (D only in the plane with bending)

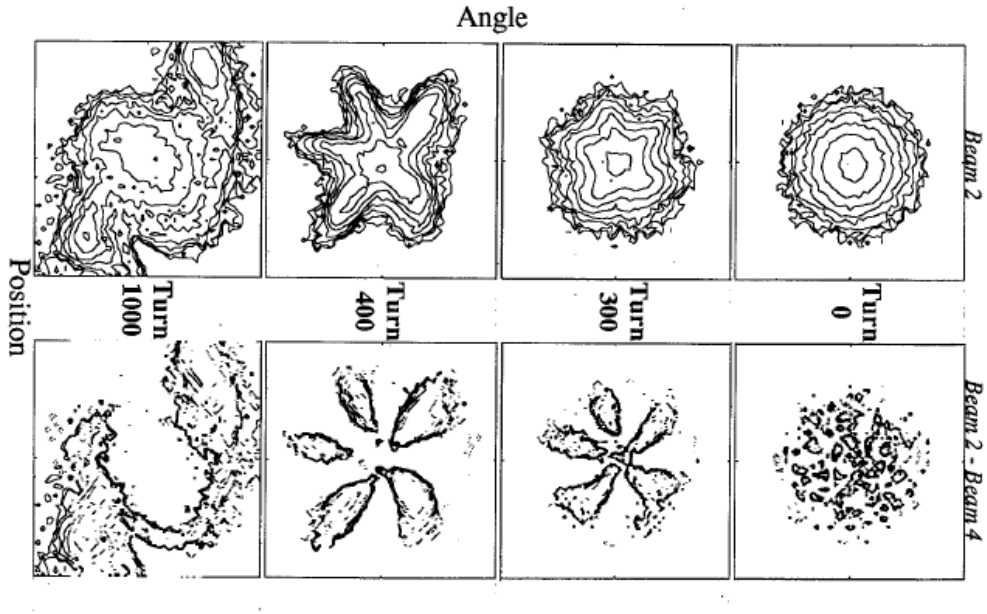
First Paper Together

PHYSICAL REVIEW E VOLUME 52, NUMBER 3 SEPTEMBER 1995

Coherent beam-beam interaction with four colliding beams

B. Podobedov and R. H. Siemann
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309
(Received 4 November 1994; revised manuscript received 12 April 1995)

The coherent beam-beam interaction in the absence of Landau damping is studied with a computer simulation of four space-charge-compensated colliding beams. Results are presented for the modes, phase space structures, widths, and growth rates of coherent beam-beam resonances. These results are compared with solutions of the Vlasov equation, and with measurements made at the Dispositif de Collisions dans l'Igloo (DCI) storage ring in Orsay, France, which operated with space-charge-compensated colliding beams.



Saw-tooth Instability History

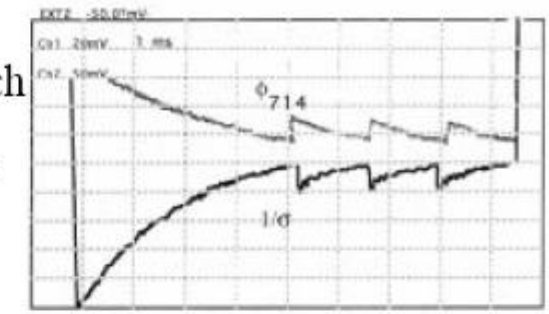
- 1992

  Attempt to raise current above 3×10^{10}/bunch

  Severe single bunch longitudinal instability

  Transient, "Saw-tooth" behavior

  Inability to operate the linac



P. Krejcik et. al., PAC-93

- 1993

  Solution - vacuum chamber replacement. Total inductance was reduced by a factor of 5.

  Simulations predicted threshold of 5×10^{10}/bunch

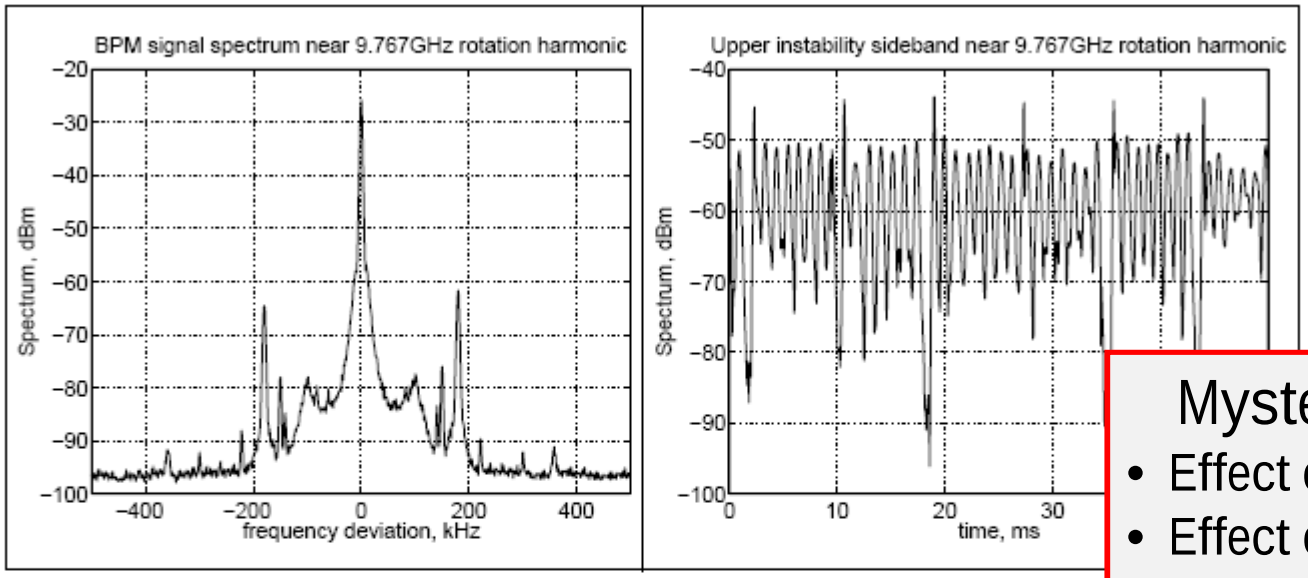
- 1994-1998

  The actual threshold went down ~2×10^{10}/bunch

  Instability less severe. Saturates at lower level. It is no longer the main limiting factor for the SLC

Instability after Vacuum Chamber Replacement

BPM Signals on a Spectrum Analyzer



Mysteries remained:

- Effect on the beam
- Effect on SLC, if any
- Instability mechanism and cause

Other Measurements

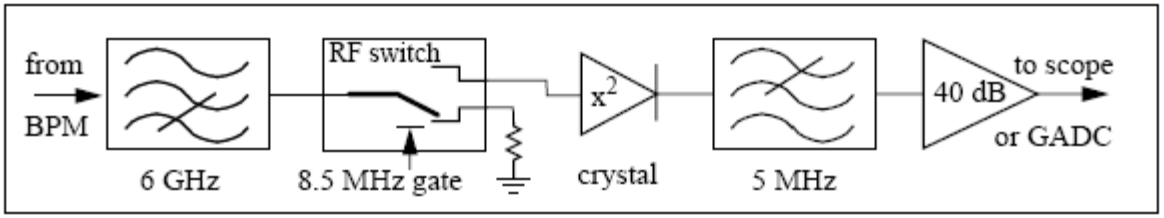
- Wire scanner - energy spread growth above the threshold
- Streak Camera - no signs of instability other than bunch lengthening
- No measurable effect on the linac

At Bob's suggestion this became a topic of my PhD

Detecting Instability Signals

Clearly a better diagnostics was needed

Detector Schematics



Cuts RF power | Separates two bunches | Detects instability signal | Removes higher frequency products

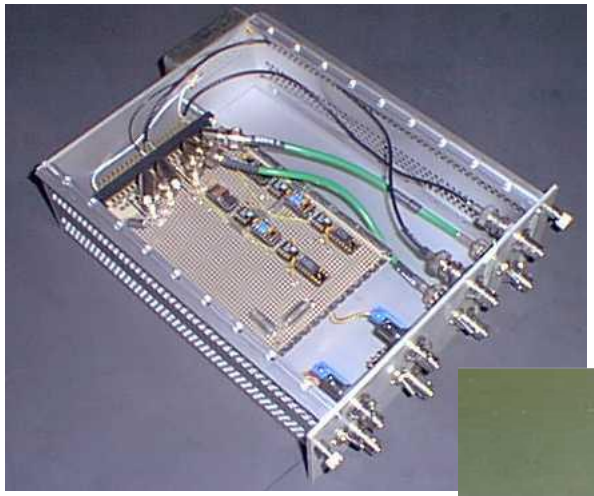
RF Switch and Crystal Specifications

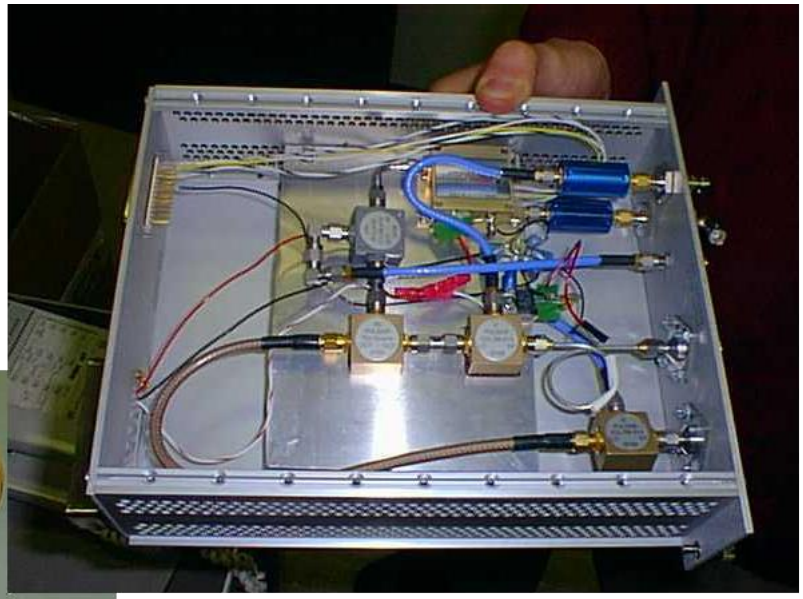
	WJ-MSE203	MITEQ-S138B	ACTP-1506N
Type	SPDT Reflective	SPST Absorptive	Square Law Detector
Bandwidth	2-18 GHz	2-18 GHz	8-18 GHz
Switching time	25 ns	20 ns	N/A
Isolation	~60 dB	80 dB	N/A

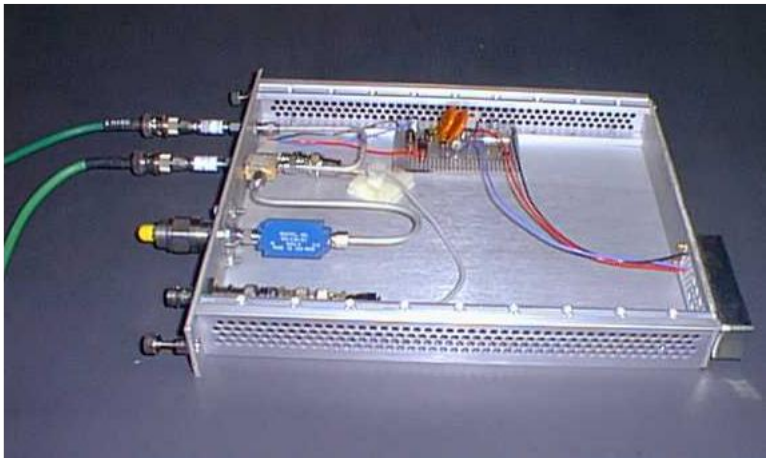
Detector

- provides single bunch "instability signal"
- the phase of this signal relates to the azimuthal orientation of the instability-induced phase space structure

Accelerator Physics Through Building Your Own Diagnostics



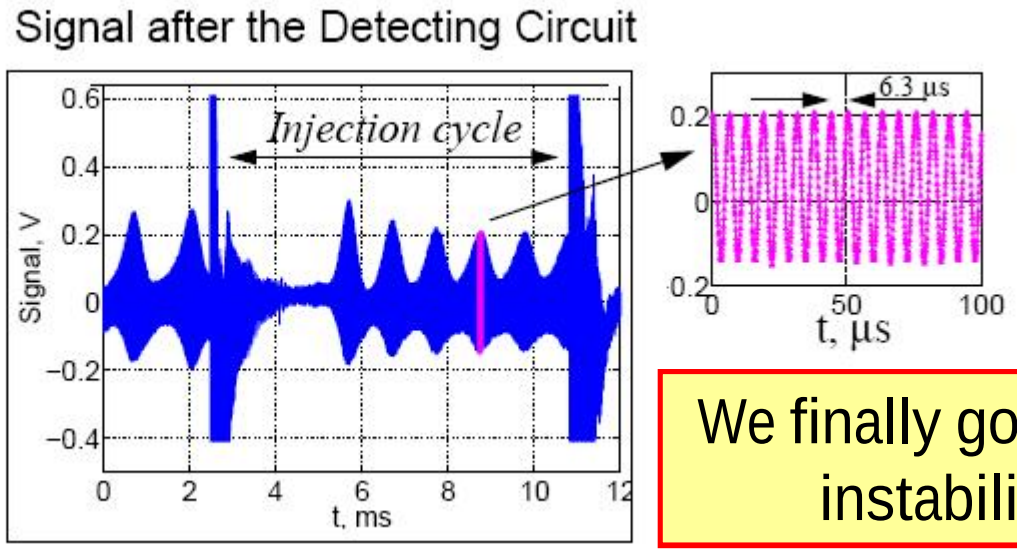




New Diagnostics Works Out

Instability frequency
160 kHz <~ 2 f_s

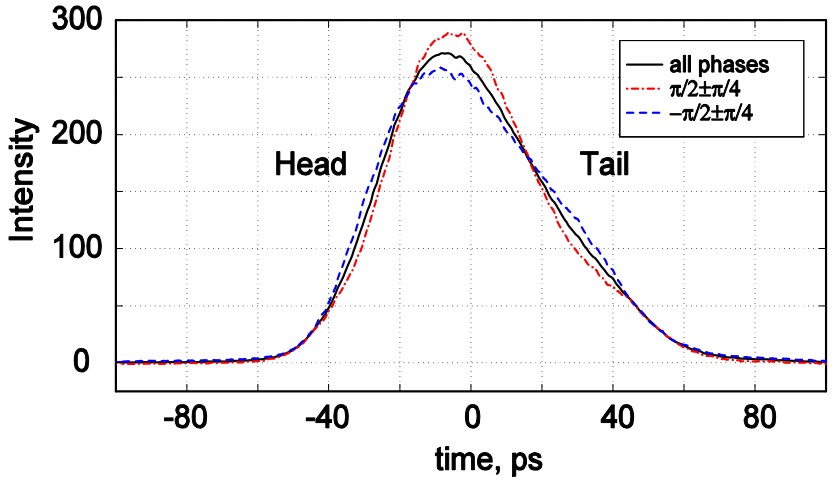
Envelope frequency
1 kHz ~ γ_d

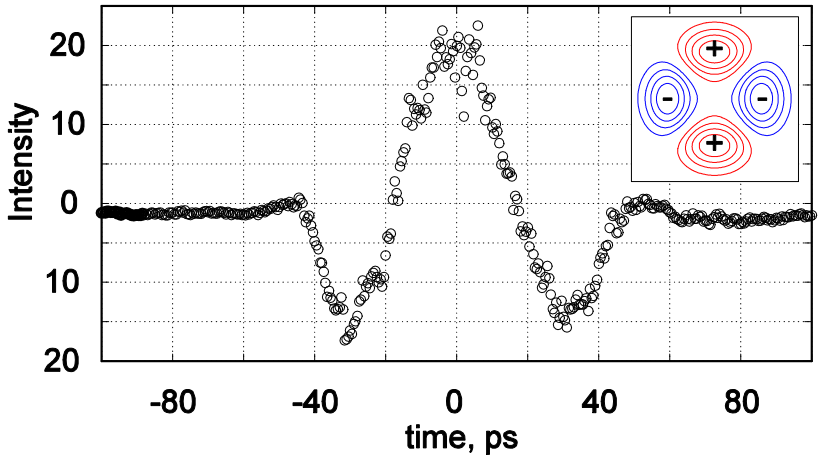


We finally got the t-domain instability signal.

We could now combine it with the streak camera

Saw-Tooth Instability: Main Results





- Recover complete phase-space picture
- Unstable mode contains ~3% of the beam
- Detector signals correlated with SLC beam downstream

PhD Thesis Writing

Second, since the instability was in a continuos mode we implemented a better fitting routine for the oscilloscope traces. Instead of relying on just two zero-crossings during one instability period we used a nonlinear least squares algorithm to fit the whole 40 μs trace with a sine-like curve with the amplitude, the frequency and the phase being the fit parameters.

With the two changes above included we processed a major portion of the data when the instability was in a quadrupole mode. Unexpectedly, we observed a strong correlation between the centroid positions of fitted profiles and their bunch lengths. The bunch length for the files in the center of the CCD was about 20% longer than for those closer to either edge of the CCD. This systematic effect of course hid the instability induced features in the beam distribution. We have traced this effect to a local sensitivity drop in the streak camera system (most likely the photocathode). To correct for this we had to boost the values for the CCD pixels from 191 to 256 by various amounts up to 14%. To find the exact correction coefficients for each pixel we used a procedure described in detail in reference [65]. As a source profile we used a sum of all the profiles from 96/97 run. In contrast to the data from the present experiment those profiles were much more uniformly distributed in their centroid positions due to larger trigger jitter. Adding this correction has eliminated the bunch length dependence on the centroid position. We have used this correction to get the results to be described next.

Please expand the discussion of this correction. What was procedure

Too short

Insert picture

Show bunch length before & after correction to justify this statement

5.2.4 Results

Using the data processing with the changes described above we have separately processed the files that correspond to the sextupole mode at V_{RF}=730 kV and to the quadrupole mode at V_{RF}= 800 kV. This choice is obvious from Figure 51. For the purposes of this section we will refer to these data as a sextupole and quadrupole batches. After making cuts in the profile area, beam current, and instability frequency and amplitude the total number of files remained in the sextupole and the quadrupole batches was 1164 and 1590 respectively. The average instability frequency was calculated to be 161.5

July 6, 1999 125

Section 4 – basically fine. Only a few small correction and questions

Section 5
– correction procedure on page 125 must be expanded upon
– would like to see comparisons of average profiles & Haissinski distribution
– where do you plan to cover the coupled bunch phenomena that you mention in closing the section?

- Bob strongly believed that thesis writing is essential part of graduate education
- Writing required many iterations
- Huge effort from Bob

What Those Theses Meant for Bob

-----Original Message-----
From: Robert H. Siemann [mailto:siemann@SLAC.Stanford.EDU]
Sent: Monday, July 10, 2000 10:40 AM
To: Podobedov, Boris V
Subject: Re: PHD stuff etc

Boris,
Your thesis in on my shelf with the others. I was telling Angie the other day that I consider those theses to represent some of my most important accomplishments - the education of young people.

Glad to hear about the success of your work at NSLS. Please consider PRSTAB when thinking about publishing it.
Bob

Graduation and Beyond


Graduation ceremony, July 1999

- I moved to BNL in Sept 1999
- We kept in touch discussing topics ranging from PRST-AB to his grad. students, and of course, Science
- My last meeting with Bob was on my SLAC visit in Feb 2007 …