HOM Transfer Function Measurements and other topics

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Applicability

- any linac with photoinjector

(context is LCLS-II)

LCLS-II Numbers

Game of subharmonics

- L-band RF is $f_0 =$ 1300 MHz
- Gun cavity is $f_0/7 = 185.714$ MHz
- APEX construction uses 1 laser pulse per 5 gun cavity cycles, 37.143 MHz

Most short-pulse lasers have rep-rate between 30 MHz and 100 MHz

99% of the documentation for the planned LCLS-II talks about the photon pulses at the photocathode, and by derivation the electron bunches, being regularly spaced at '1 MHz', sometimes with the footnote that this is really 928.6 kHz.

- One nominal bunch every 40 laser pulses

What's in a laser?

"A chain of 4 pre-amplifiers gets the seed from the oscillator. After the first two pre-amplifiers, the repetition rate is decreased to 1 MHz by a acousto-optic kicker (AOM), driven by a 2 W 100 MHz pulsed rf signal synchronous with the oscillator. The AOM's rise and fall time are at the 20-30 ns level."
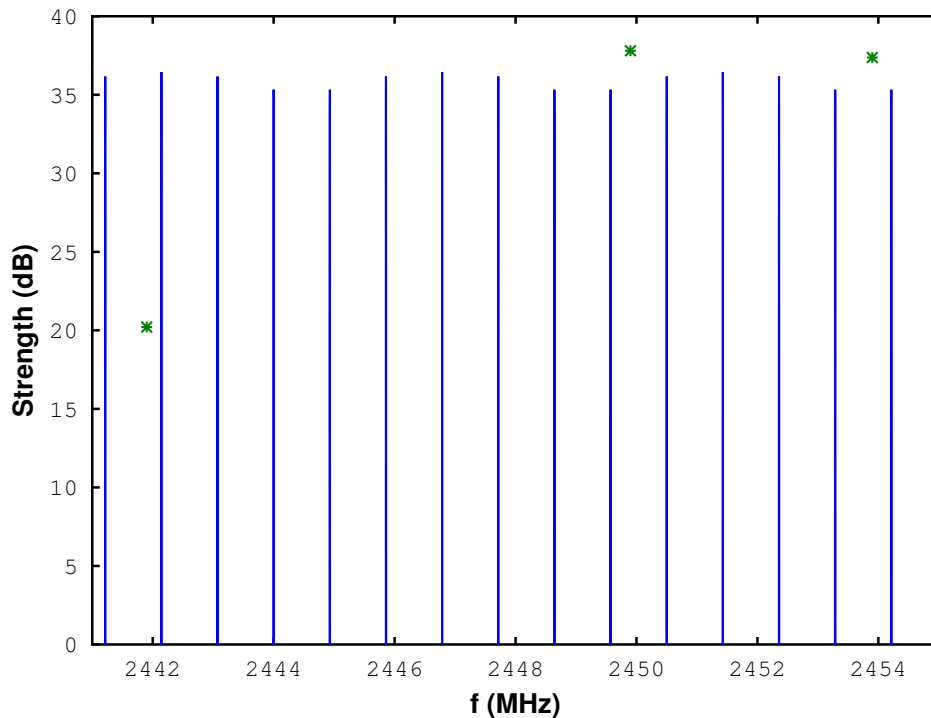
• The Photocathode Laser System for the APEX High Repetition Rate Photoinjector D. Filippetto *et al.*, Proceedings of FEL2013

Flexible!

There are many limits to how often the AOM can be fired, but especially at low bunch charge, it is pretty much pulse-on-demand subject to the 26.9 ns granularity, and keeping approximately 1 pulse per microsecond or less over tens of microseconds.
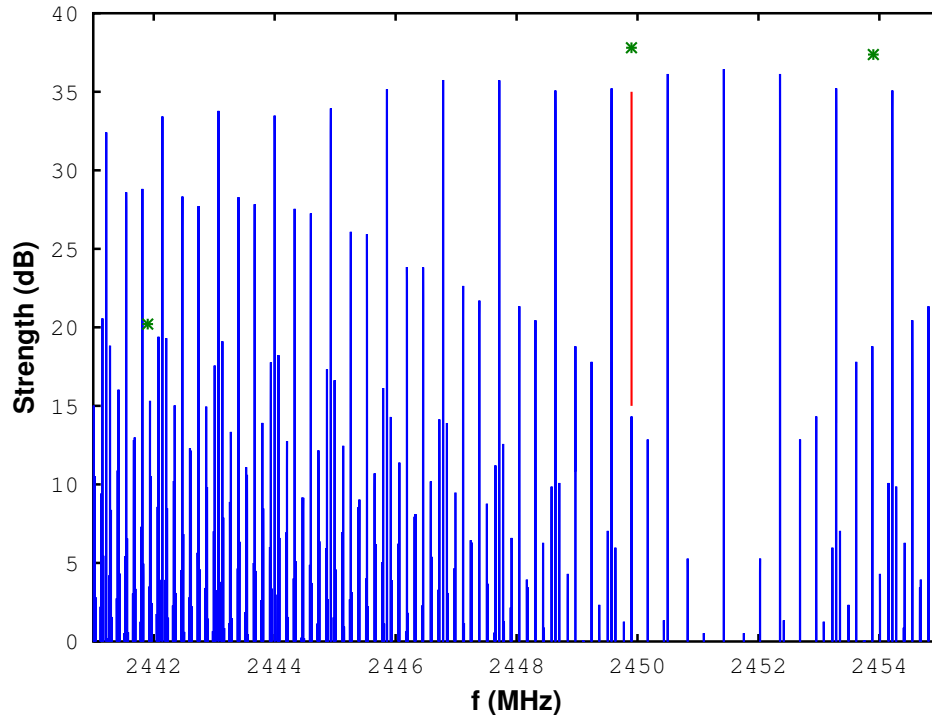
Normal

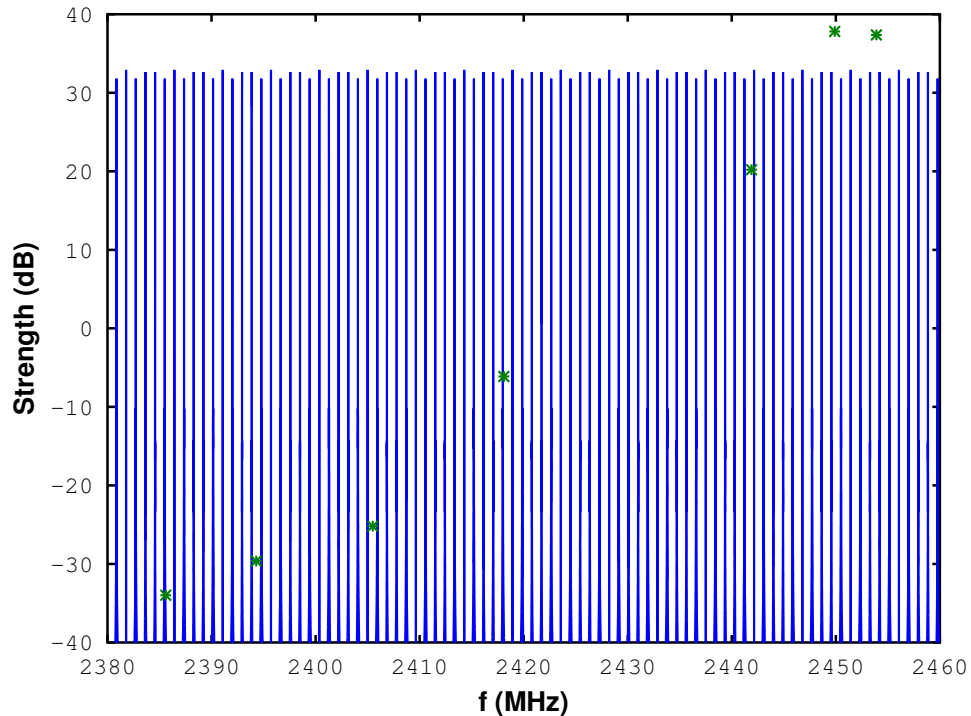Usual spectrum of '1 MHz' beam, with TE_{111} mode impedances shown.

Abnormal

Same conditions, but jiggle each pulse's timing $\pm 13\,\text{ns}$ to hit $2449.9\,\text{MHz}$
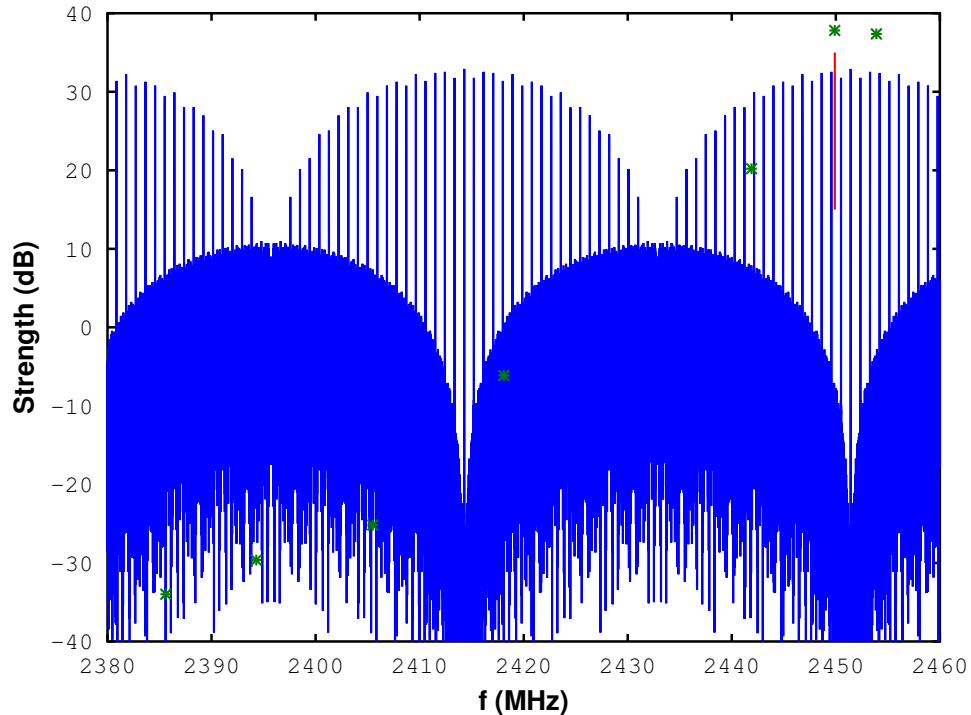
Normal

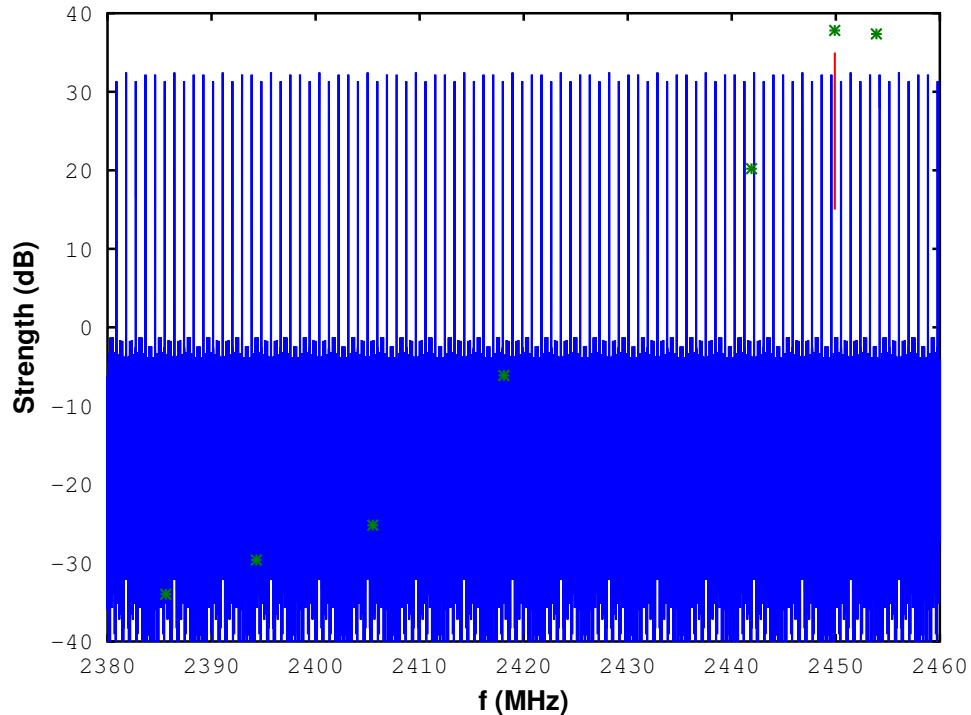Usual spectrum of '1 MHz' beam, with TE_{111} mode impedances shown.

White phase noise added

Random jitter modulated

White amplitude noise added

Random 5% pulse dropouts

Transfer function

- Excite from photoinjector
- Couple to monopole cavity mode
- Synchronous RF measurement on HOM probe (or fundamental probe)

Timing system planned for LCLS-II is flexible enough to synchronize this stimulus/response over whole accelerator site
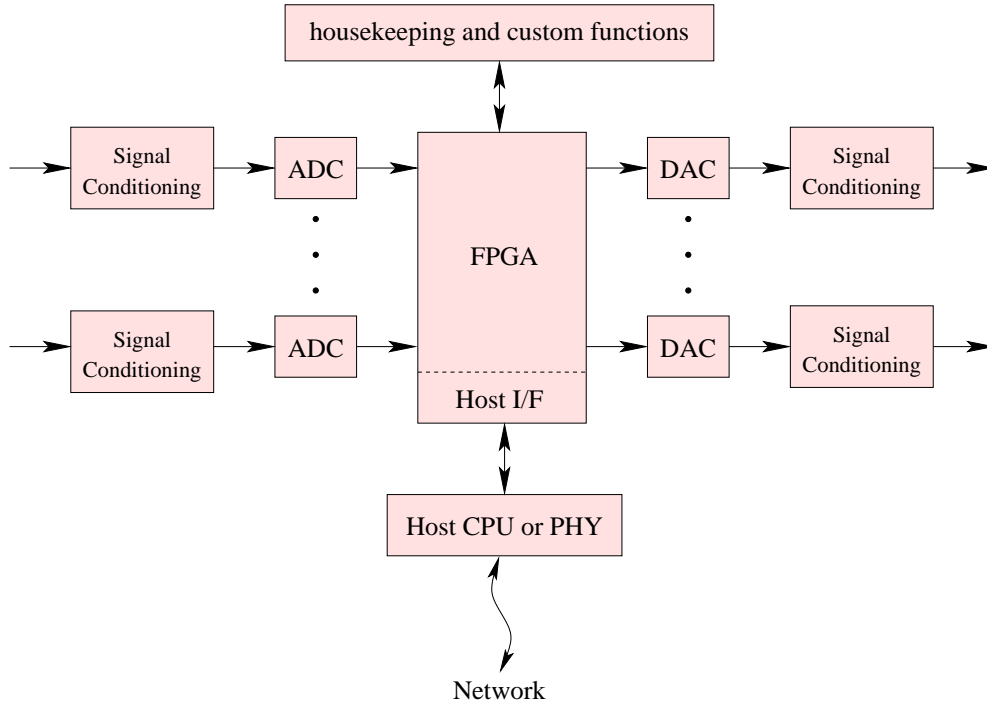
Alternative

Modulating the bunch charge, as described by Daniel Hall of Cornell, is perhaps simpler to think about. But a full linac's longitudinal bunch propagation is sensitive to bunch charge due to short-range wakes. Nothing in the system besides HOMs (and presumably the end-station photon experiments) is sensitive to ± 13 ns changes in bunch arrival time.
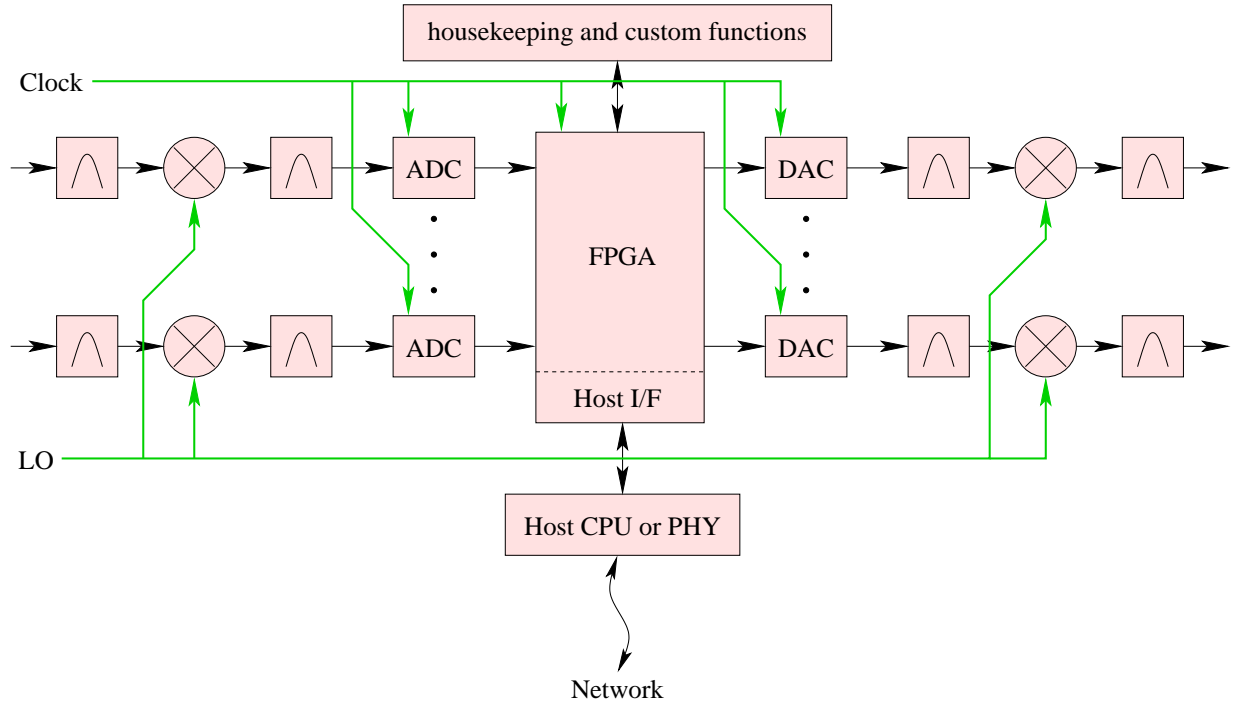
Conclusions

- Photoinjectors don't have to be operated only at their nominal setting
- Pulse-on-demand feature can be used as a programmable frequency source to excite (or avoid exciting) HOMs at any frequency
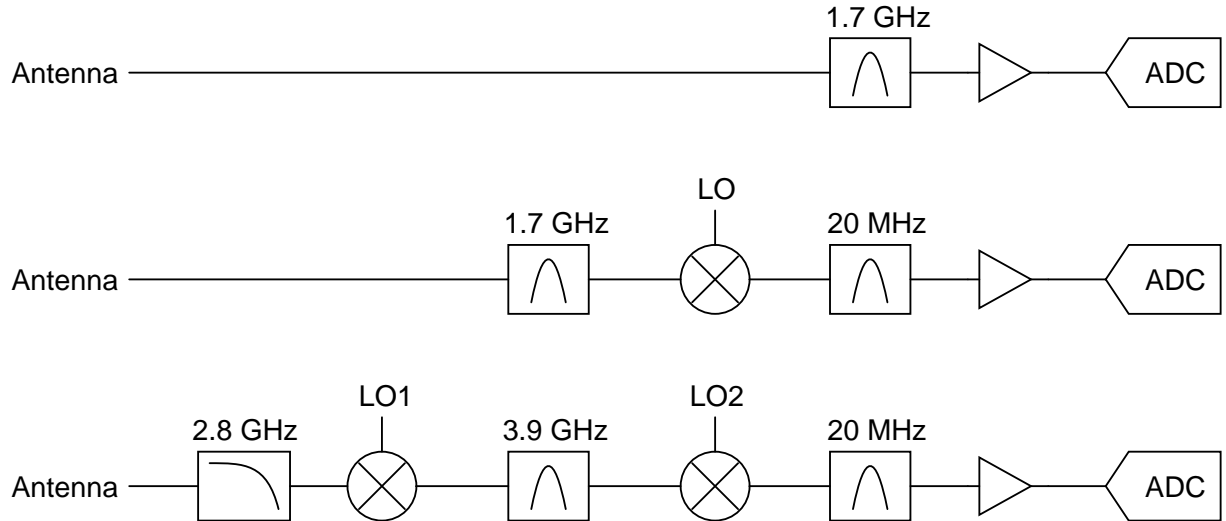
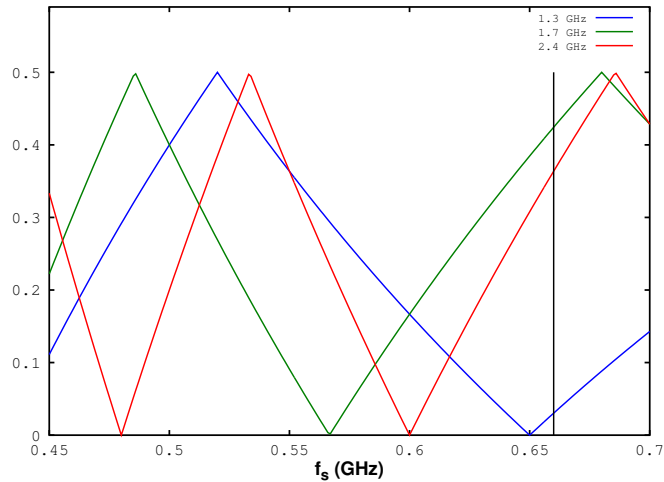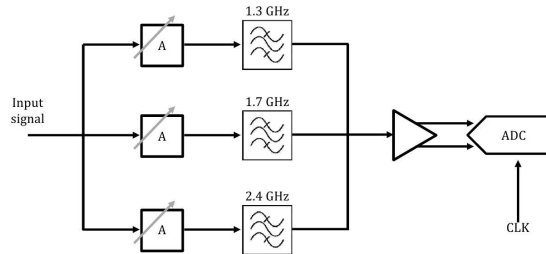**Thanks for listening!**

Familiar Block Diagram

Familiar Block Diagram

Data Acquisition

Data Acquisition - DESY/Bou Habib

Data Acquisition - LCLS-II LLRF compatible

1320.0 MHz downconversion LO — x3 — 3960 MHz HOM second LO

2-board set, plus off-board 3954 MHz cavity filters (20 MHz BW)

HOM Antenna

1200-2800 MHz?

HOM Antenna

3940 MHz

3940 MHz

20 MHz

20 MHz

20 MHz IF

20 MHz IF

1200-2850 MHz

÷16 — 75-177 MHz freq. monitor

VCO
5100-6800 MHz
HMC586?

188.57 MHz reference — PLL

ADF4106?

Access to fundamental (1300 MHz) frequency allows software interlock on excessive bleed during cavity bring-up (notch filter failure)