Summary of injector parameters and diagnostics needs for a 100 mA Injector

(or diagnostic beamline design for the JLab 100 mA Injector Test Stand)

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Injector Diagnostics Philosophy

- Want to shorten the beamline as much as possible so there is not much room for diagnostics, but…
  - Need enough diagnostics to set up the beam per the model (PARMELA) using beam-based measurements
  - Need a diagnostic for each adjustable parameter (knob)
  - Want to study limiting phenomena like halo and beam stability.

Expected injector parameters from PARMELA*

Parameter	Charge 135 pC
E (MeV)	7.66
σ_E (%)	0.5
σ_z (ps)	6.0
$\sigma_{x,y}$ (mm)	0.69
ε_{Nxy} (mm-mrad)	1.0
ε_{Nz} (keV-ps-rms)	44**
Iavg @ 750 MHz (mA)	101

*Modeling by H. Bluem, AES.
**May get better when modeling 135pC with 3rd harmonic cavity

Basic parameters set by design/model

Measurement	Method	Diagnostic	Resolution/Accuracy
Charge	Measure Beam current (macropulse & CW) & divide by repetition rate.	Faraday cup or BCCM	0.1% / 1.0%
Energy	Spectrometer	Dispersion section (~0.5m) + BPM and/or beam position in viewer	0.02% / 0.25%
Energy spread*	Measure beam size at dispersed location.	Dispersion section + viewer + framegrabber	0.03% limited by transverse spot size
Bunch length*	Measure Cerenkov light pulse	Cerenkov viewer + Streak camera	1.0 ps nominal
Transverse emittance	Phase space sampling	Multislit + viewer. Cross-check with wire scanner	0.1 mm-mrad-rms / ?
Beam spot size	Direct measurement with framegrabber	Viewer + framegrabber	Set by framegrabber resolution (tens of microns)

* With these two measurements we can map out the longitudinal phase space

Beam transport and beam optics

Device	Diagnostic	Resolution/Accuracy
Steering coils/correctors	BPMs and viewers	0.1 mm/1 mm in position
Quadrupole pair	BPMs, viewers and multislit	TBD
Cavity phases	Spectrometer + BPM	0.5 deg / 1 deg
Cavity gradients	Spectrometer + BPM	0.01% / 0.5%
Focusing solenoid	Viewer & multislit	Set by limitations of using model based study

Other measurements performed in CW mode (100 mA)

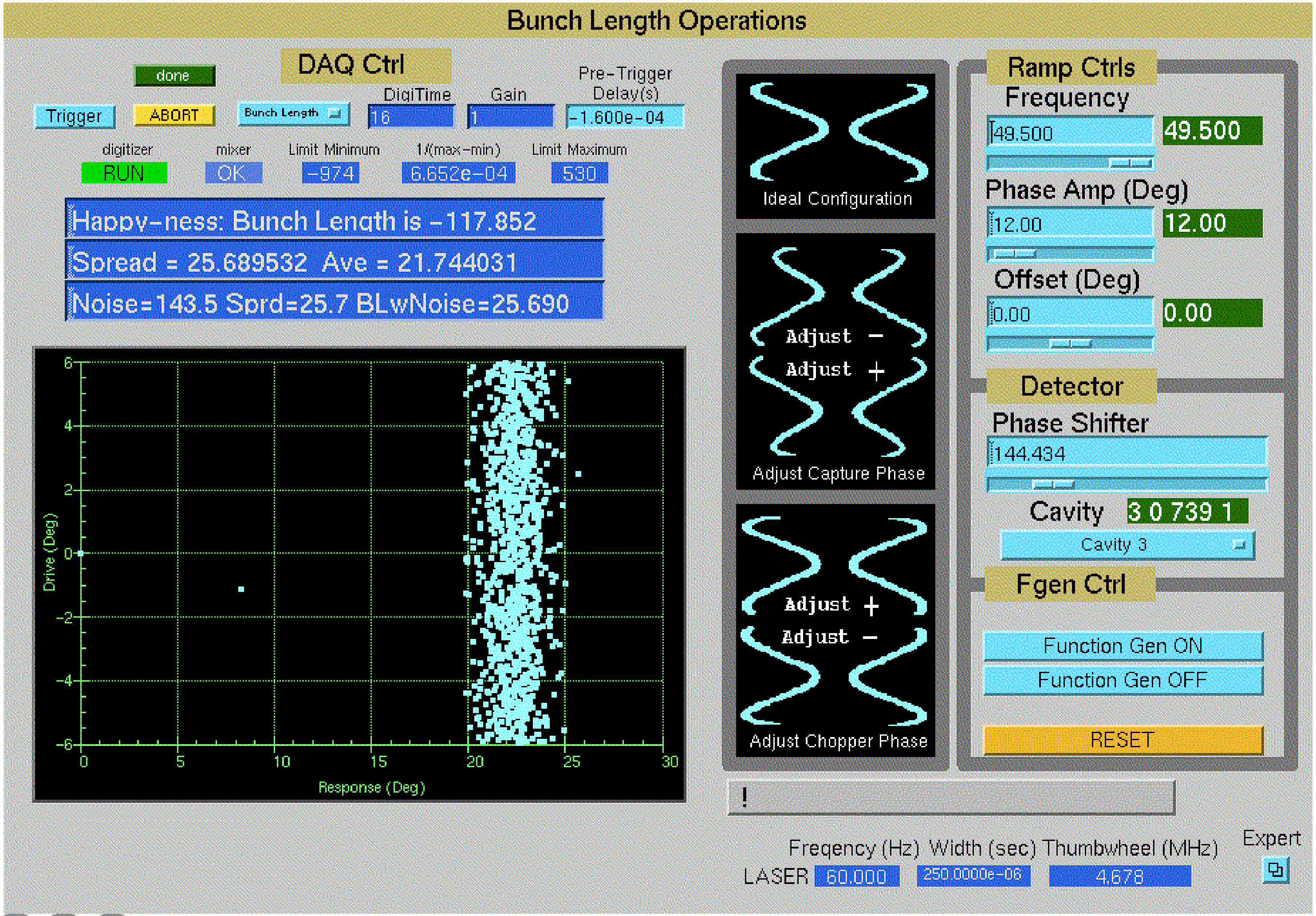
Measurement	Diagnostic	Resolution/Accuracy
Beam current	Faraday cup at beam dump (~700kW), BCCM, HVPS current monitor.	0.1% / 1%
Halo (10^{-5} to 10^{-6} range)	Integrated apertures, sensitive viewers with holes for sync light corona Measure radiation from aperture or scanning wire	10nA / 10nA
Beam transverse size	Flying wire? Suggestions welcome.	TBD

Beam stability measurements: The RF system is also a good diagnostic

- Gradient and phase error signals can be measured and noise levels can be established
- The Beam Current Cavity Monitor (BCCM) can be used for time jitter measurements
- Can use BPMs for trajectory and energy stability

The M55 cavity system can map out phase response of any of the elements in the injector

(See G. Kraft's talk in WG4 session 1)



But also, we need to consider what DOESN'T work in injectors

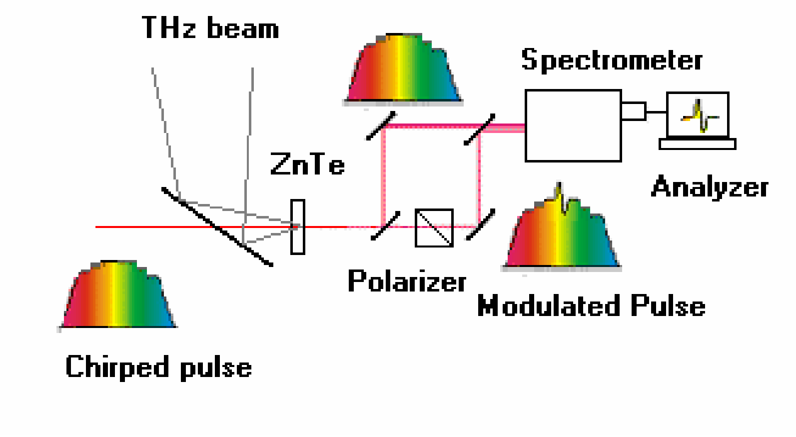
- A COTR interferometer device does not work due to the long bunch
- OTRs performed poorly at low energies
- Synchrotron light monitors don't work below 20 MeV
- Multipass BPMs are unnecessary
- Electro-optics sampling does not work in its traditional form, although a fs laser can be used to measure the coherent synchrotron radiation emission in the THz region (See S. Jamison WG4 session 1)

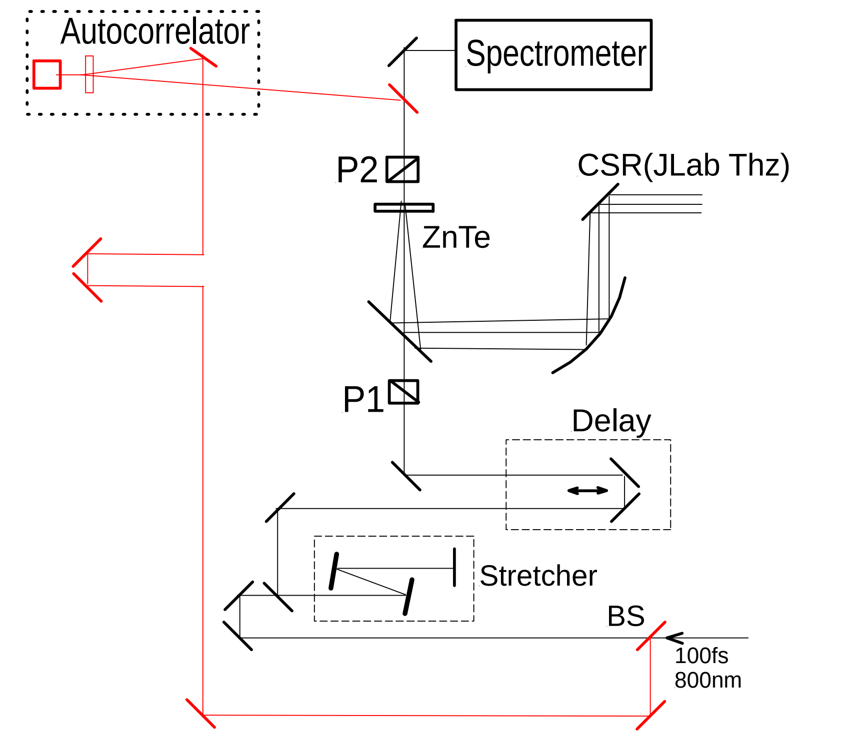
Bunch Length Measurement by EO Sampling
(courtesy S. Zhang, JLab FEL)

• We have set up an EO sampling system to measure the shorter (<500fs) bunch length which is beyond the steak camera capability.

• Thz-pump chirped-pulse-probe scheme

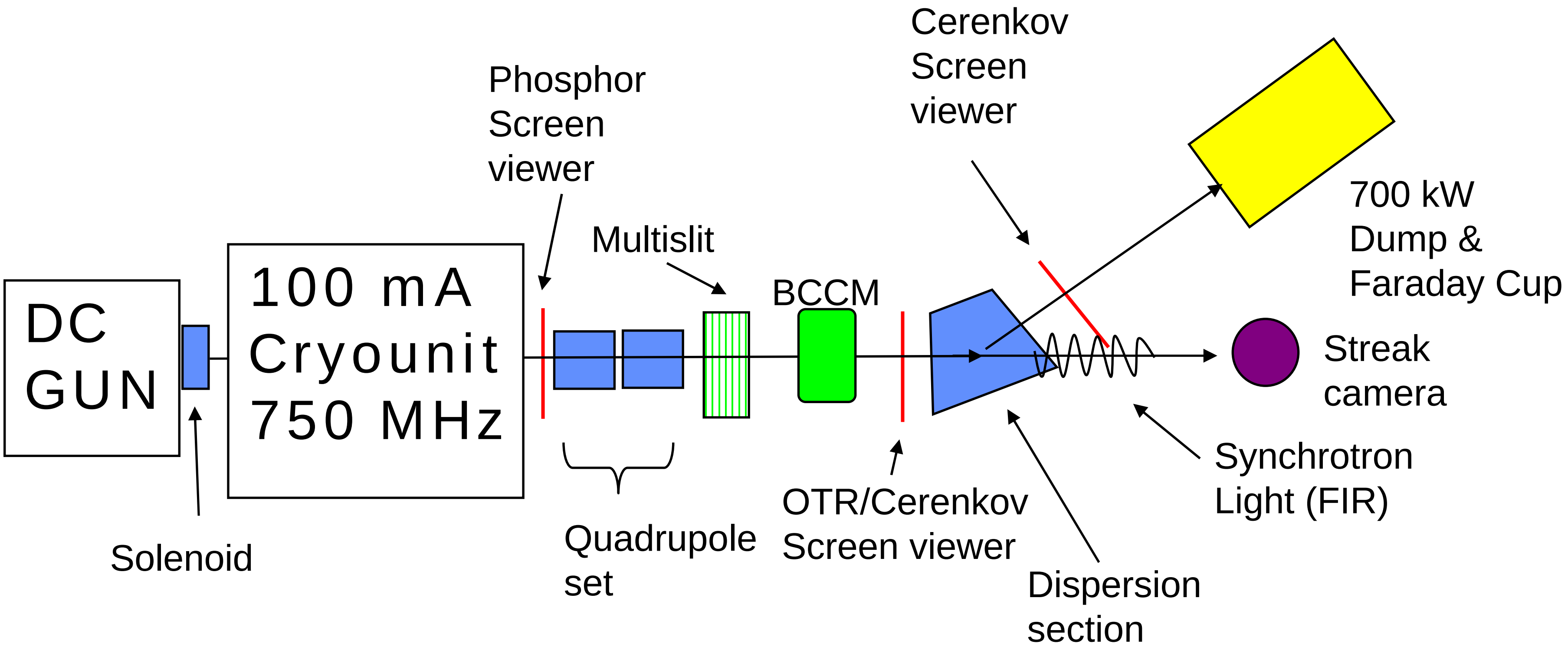
Concept: A chirped-pulse probe detection system is used to map the modulation on the linearly dispersed spectrum of the probe induced in EO crystal by the THz electric field. In stead of doing the time delay scanning, the temporal profile of the THz pulse can be obtained from the probe spectrum which has been modulated (by X-C Zhang etc.).



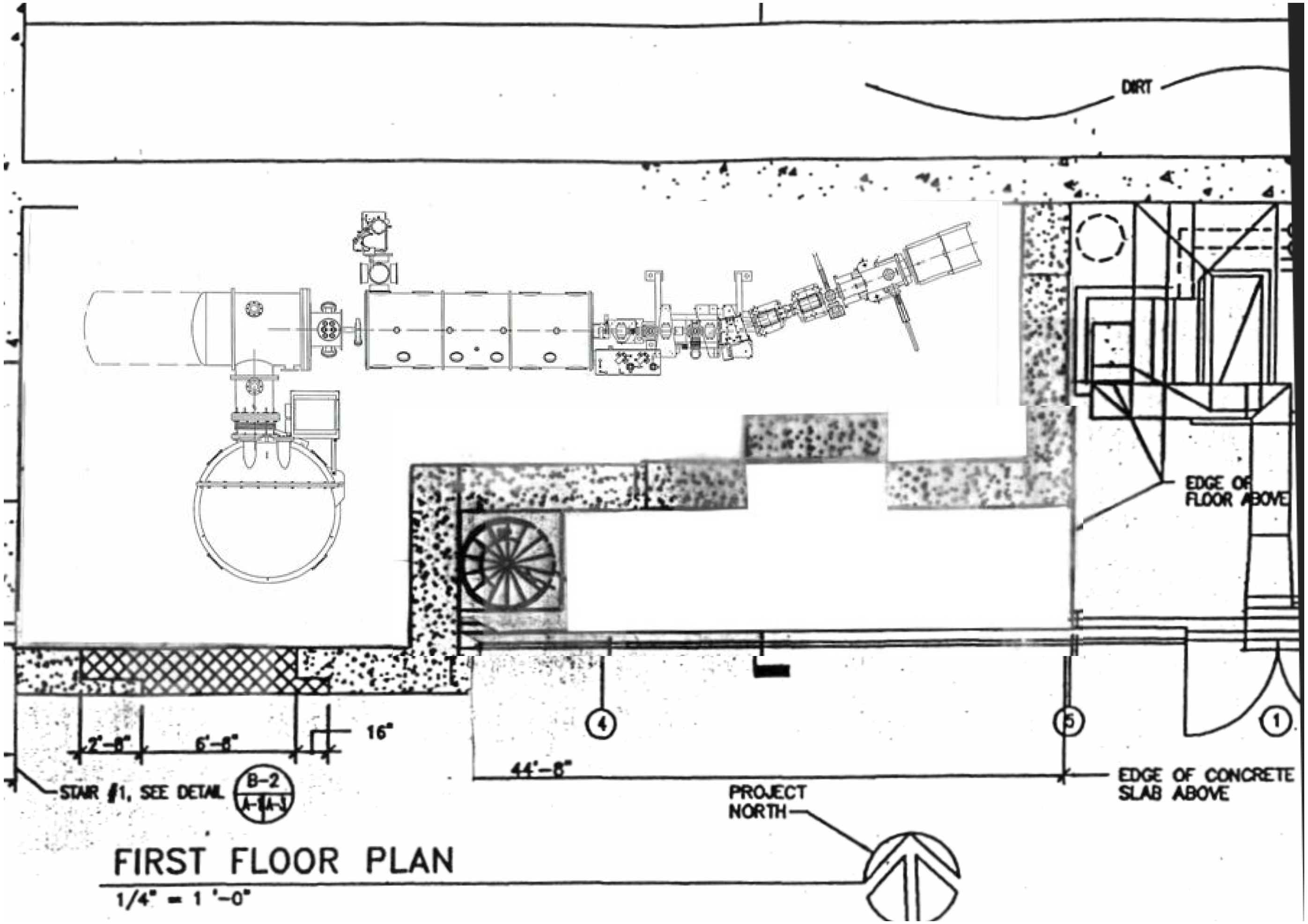


Beam Bunch Length Measurement by EO Sampling

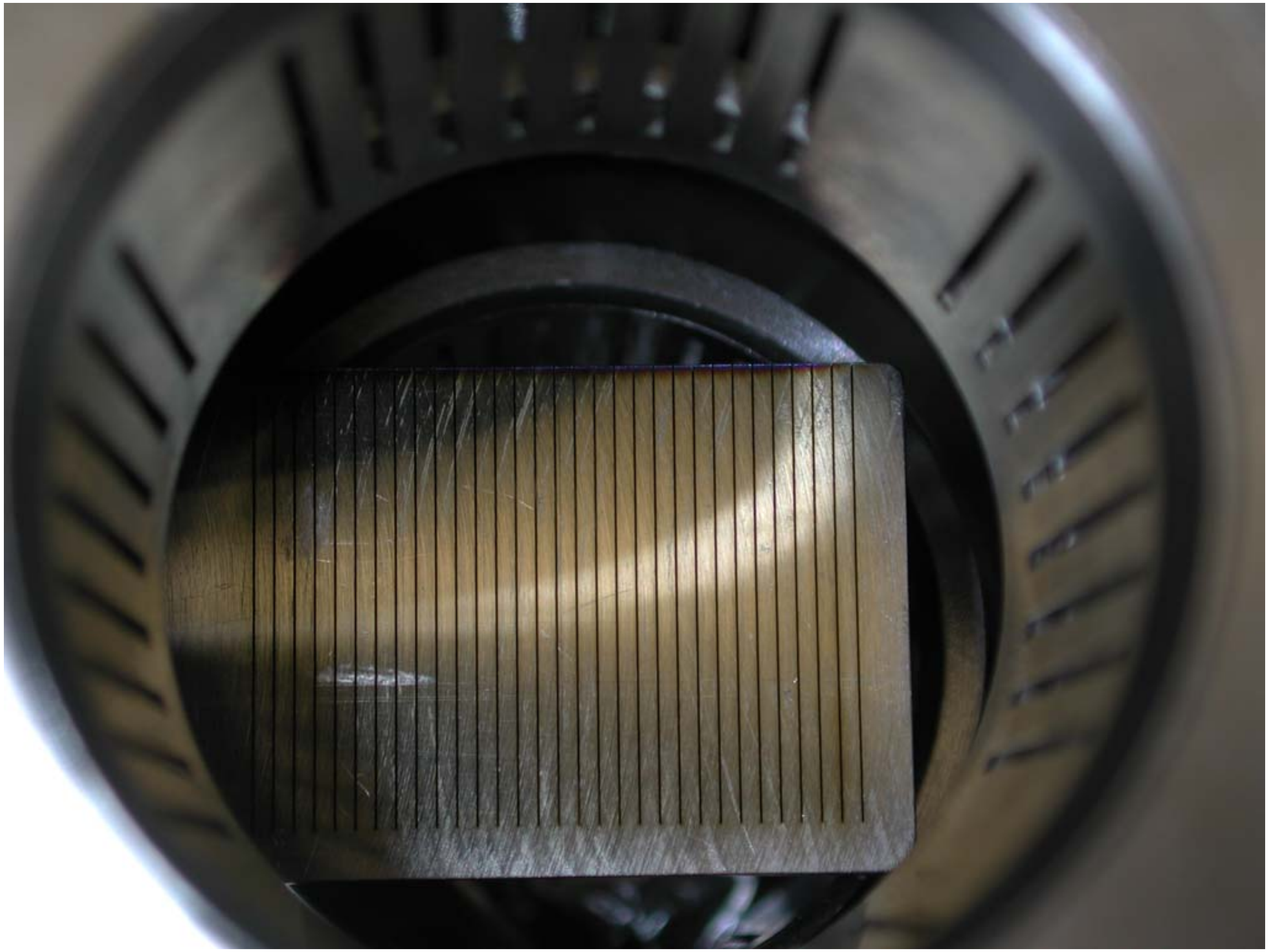
100 mA injector diagnostics beamline block diagram



100 mA injector and diagnostics beamline layout shown inside JLab Injector Test Stand (ITS) facility (under construction)



New multislit



Open questions

- What are the procedures necessary to set each knob in the machine? Need to develop beam-based measurements to establish procedures.
- Are there any changes expected in the beam phase space when switching from pulse to CW mode?
  - If so, what diagnostics (non-invasive) can be used in CW mode (like BPMs to infer any change in transverse beam size)
- We intend to test 1 nC/bunch in pulse mode with this injector. Will the discussed diagnostics work at that charge?
- Will the multislit method work for >1 nC/bunch? Space charge may be large enough to distort the beamlets by the time they arrive to the screen

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