PXIE LEBT Commissioning Update

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Content

- Shutdowns and main achievements
- Chopper commissioning
- Plan
Previous setup

- Last report (9/30): Beam through 3 solenoids for the first time
  - Starting a shutdown to install the chopper
Current setup

- Two shutdowns:
  1. Chopper installation, remove Isolated Diaphragm #2, fix emittance scanner, move solenoid PS to mezzanine and vacuum control equipment out of the cave (3 weeks)
  2. Reinstall emittance scanner (in horizontal position), replace original ‘donut’ with water-cooled version (3 days)
Beam line plan view - Section

- All (optical) elements are in their final/designed position
Setup in picture

- DCCT
- ‘Diagnostics’ box
- Gate valve
- Chopper assembly
- Water-cooled donut connectors
- Emittance scanner (not visible)
Chopper assembly in pictures

- Absorber water hoses connectors
- Kicker HV cable
- Ion gauge
- Collimator connectors
- IR viewing window
- ‘Diagnostics’ box
- Turbo pump
- Chopper modulator
Emittance scanner in picture

Water-cooled donut connectors

Faraday cup

RGA Head

Emittance scanner
Solenoids power supplies moved to the mezzanine

Cable trays going across

Current regulation electronics

Spare solenoid PS
High current transport

- Achieved 10 mA with $\lesssim 2\%$ losses after the first solenoid (down to the Faraday cup) both in pulsed and DC mode
  - Configuration without the diagnostics box i.e. FC right next to the last solenoid
  - Losses on collimator and donut are on the order of 0.1 mA
  - Up to 11 mA in pulsed mode
    - Reminder: we are intentionally scraping the beam at the exit of the ion source vacuum chamber and there is another 0.1-0.5 mA lost on isolated diaphragm #1 (depending on beam current)
  - Removing the isolated diaphragm in solenoid #2 makes a big difference
    - Can make it through without steering, which was not the case before even for low current
Estimation of neutrals production from donut calorimetry

- Apr-14: ~9% of H⁻ are converted into fast neutrals at the exit of the IS
- Estimation for 3-solenoid setup: ~8% reach the donut
- Donut calorimetry agrees within a factor of 2
- The temperature growth is the same with chopper on and off
- Estimation of neutrals’ “current” that would fly to RFQ: 0.01 mA

The donut temperature growth rate, adjusted for cooling losses, as a function of the product of the H₂ flow rate and beam current
Chopper performance

- Up to 10 mA DC diverted onto the absorber
  - ~100% ‘efficient’
    - Virtually no beam on collimator (i.e. isolated diaphragm just downstream of the chopper proper) and donut
  - Default status \(\equiv\) Beam deflected
    - -5 kV applied to kicking plate
    - Absorber is grounded
      - Could be biased
  - Unexpected positive current on the kicking plate
    - ~20% of total primary beam current
      - \(H^+\) reflected as proton?

Glow of the absorber plate for a 10 mA beam (-5 kV deflecting voltage)

16 cm
32 mm
~2 cm
Short pulse operation

• First attempt at creating ‘clean’ μs-long pulse
  ▪ Chop beam near the end of the ion source pulse in order to let the beam reach a near steady-state

  For instance, for RFQ commissioning
Short pulse - Proof of principle

- 5 mA DC ⇒ 1 μs chopped beam

16 trace-average

Zero current on absorber plate i.e. beam passing through

Image currents during HV switching

Absorber plate

Toroid (unknown calibration)
Emittance scanner repair

- Short on top deflecting plate
  - Attributed to deteriorated HV cable shield

Metallic particulates
Operational notes

- Since October shutdown, no IS discharge!
  - No apparent reason even though we ran DC quite a bit
  - Also added capability of remotely resetting if it happens
- Added current regulation to solenoids PSs
  - In addition, increased cooling capability with ‘new’ heat exchanger
First steps toward synoptic display

- Bill Marsh built the first version for the LEBT
  - Requested help from Operation Dpt. (M. Olander, who helps with the Sequencer already)
Status vs. Goals

• 5 mA DC with $\varepsilon_{n,\text{rms}} < 0.15$ mm mrad
  ▪ **Specs:** $\varepsilon_{n,\text{rms}} \leq 0.25$ mm mrad
  ▪ **Caveat:** Beam parameters ($\alpha$, $\beta$) not matched to RFQ’s
    ✷ Because of the small beam size required at the entrance of the RFQ, the emittance will increase (w.r.t. today’s best)

• Up to 10 mA (DC and pulsed) through 3 solenoids with losses <2%
  ▪ **Specs:** <10%
  ▪ **Caveat:** Emittance measurements (until now) not trustworthy > 5 mA, so cannot ascertain $\varepsilon_{n,\text{rms}} \leq 0.25$ mm mrad for high current
    ✷ However, the present measurements are very likely over estimating the emittance at high current

• Chopped pulse 1 $\mu$s-long at 10 Hz with rise-fall times $\sim 80$ ns
  ▪ **Specs:** 200 ns at 60 Hz with rise-fall times $\leq 100$ ns
    ✷ Measurement does not show any indication that specs cannot be achieved
Short term effort

• Demonstrate beam parameters matched to RFQ’s
  ▪ Highest priority to claim “RFQ commissioning-ready” status
  ▪ Progress in the understanding of the beam line optics
Long term effort

- **Work toward long run capability**
  - Demonstrate 24 hours of continuous running without ‘experts’ needed
    - High priority
- **Add scraper and beam stop**
  - Scraper: RFQ vane protection (and on-line beam measurements)
    - Detailed design has started
  - Beam stop: Personnel protection
- **Implement Machine Protection System (MPS) to limit the total average current delivered to the RFQ**
“RFQ commissioning-ready” assembly

- For commissioning of the RFQ, gate valve needs to be replaced with true beam stop for personnel protection
  - Eventually, the bend will replace the beam stop
LEBT ‘scraper’

- Movable isolated electrode with holes
  - Beam measurements and RFQ protection
Outlook

- On-track to be ready for RFQ arrival in the Spring but...
  - Requires additional effort (i.e. people) for MPS and personnel protection scheme
  - Requires sustained effort in the design of the beam stop
    - It’s a *somewhat* complicated component!