PXIE absorber test bench

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Project X meeting

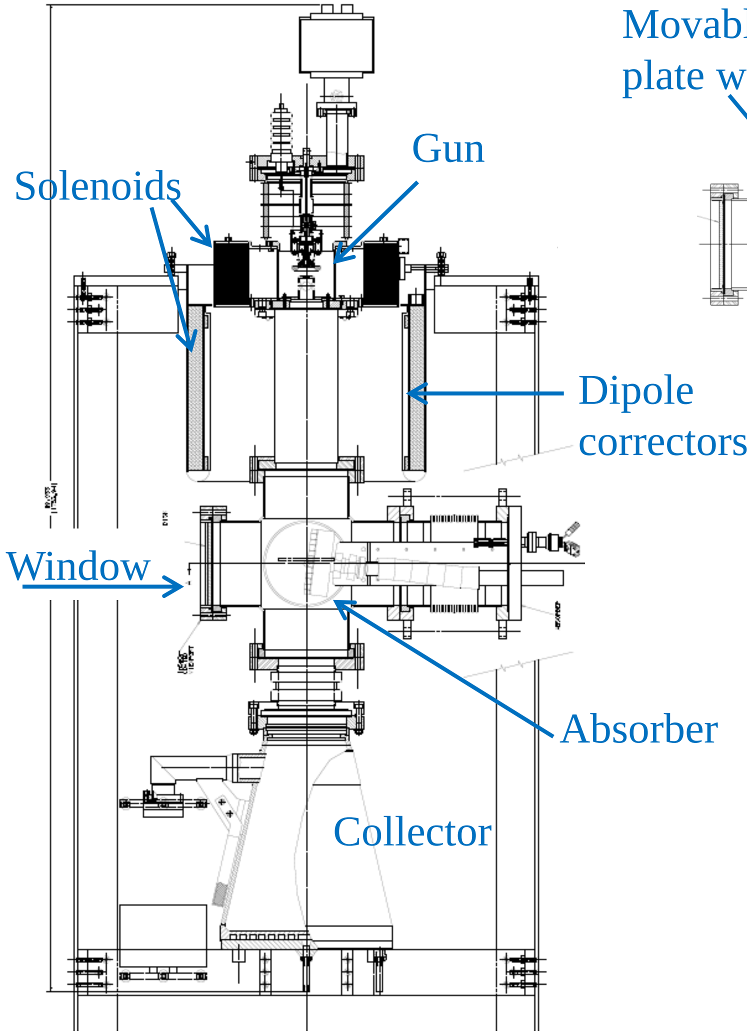
- Test bench description
- Difficulties: outgassing and reflected power
- Beam imaging
- Summary

Goals

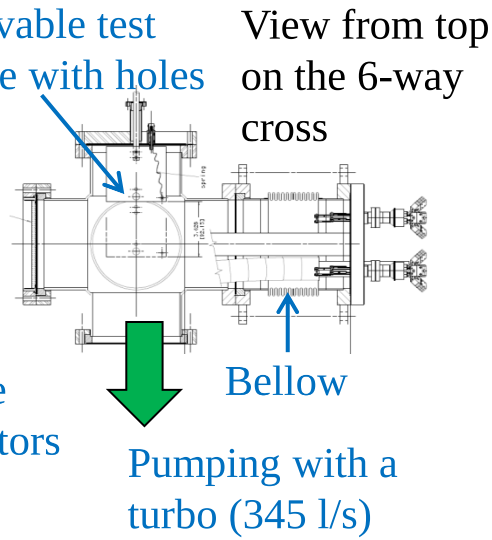
- Final goal:
  - thermal testing of the absorber prototype with an electron beam
    - Model the thermal load from 21 kW H- beam to an absorber at the grazing angle of 29 mrad
    - Will be done with a 30 keV, 0.2A electron beam at ~120 mrad angle

- Preparation:
  - Get the required beam current
  - Characterize the e- beam
  - Develop procedures for testing
  - Understand difficulties and limitations

Test bench description



Designed and assembled by Jim Walton mainly from Ecool parts



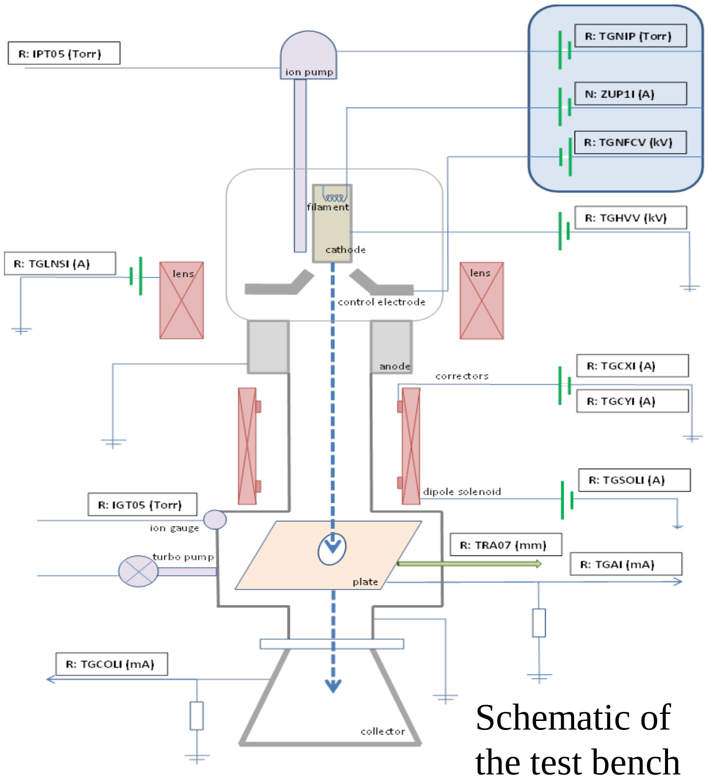
HV: 30kV, 200mA max

- Pumping:
  - Test chamber - 300 l/s turbo
  - Gun: 20 l/s IP
  - 10mm anode diaphragm

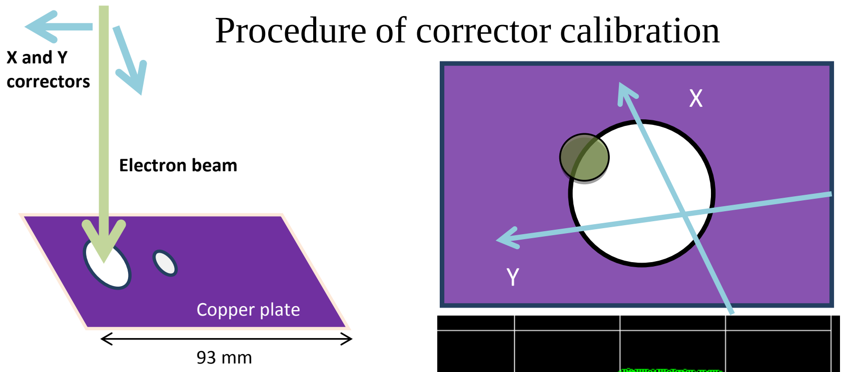
- Current reading:
  - HV PS (cathode), collector, test plate
- Water flow
- Temperatures
  - Absorber, chamber, water in/out
- Camera to image the absorber surface

Calibration and initial tuning

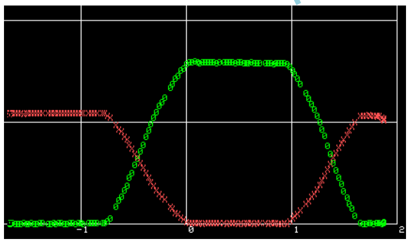
- First stage: beam size measurements -done
  - Scans over round holes in a movable, electrically isolated plate
    - A. Mitskovets (PARTI student): commissioning, calibration
    - Low-current DC (0.4 mA) or long-pulse mode (0.3 sec)
    - Found solenoid settings to provide the power density close the requirement



Schematic of the test bench



Procedure of corrector calibration



Example of a low-current beam scan over a hole

Beam size measurements with a long-pulse beam

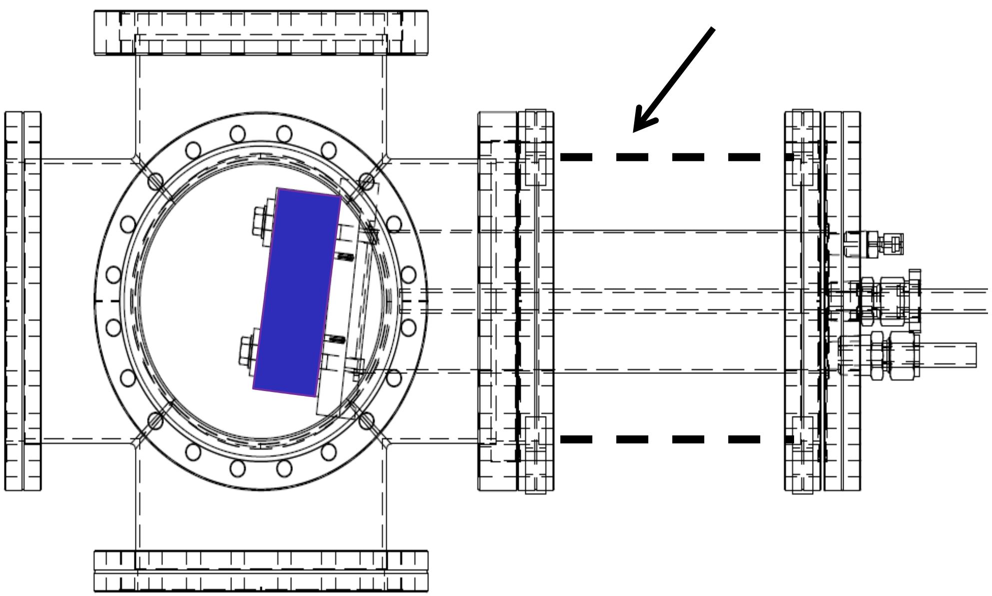
88mA: beam cross section is a good circle of 3.3 mm diameter with a well-determined boundary.

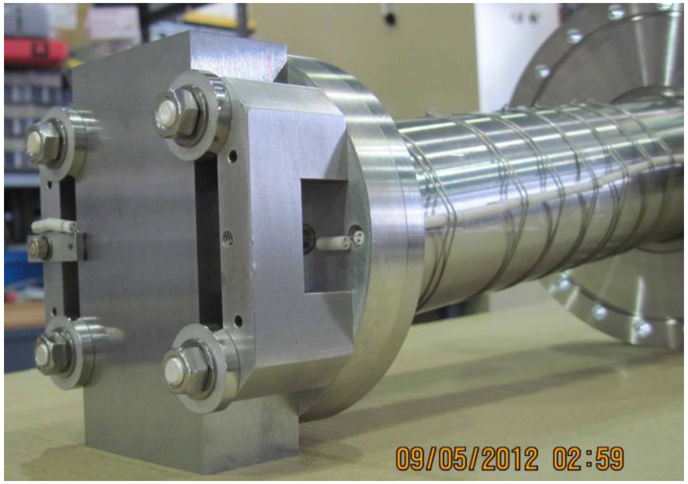
160mA: 7.7 mm diameter

Pre-prototype

- A simple absorber to start developing procedures and to commission the test bench
  - A TZM block bolted to a water-cooled plate
  - Designed, manufactured, and assembled by Jim Walton
- To develop procedures of working with a high-current (~100mA) beam

Long bellow to insert the absorber into the beam or remove it out

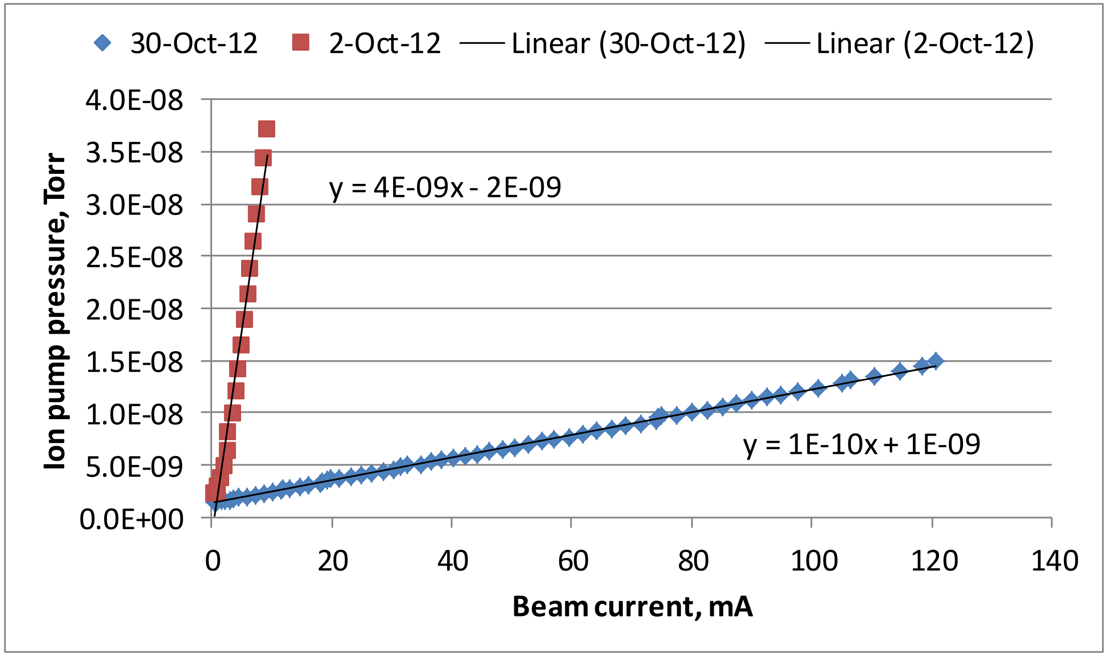




Difficulties

- "Normal" commissioning issues
  - For example,
    - Killing the cathode by bumping a turbo's cable
    - Radiation from an uncovered gap (resolved)
    - HV PS current readback doesn't work at high currents (IRM problem)
    - …..
- High beam – related outgassing
  - Cathode poisoning
- Unexpectedly high power in secondary (reflected) electrons
  - Heating the vacuum chamber by secondary particles
  - Decrease of power deposited on the absorber
- Secondary concerns
  - Darkening of the vacuum window
  - Damaged test plate

Outgassing

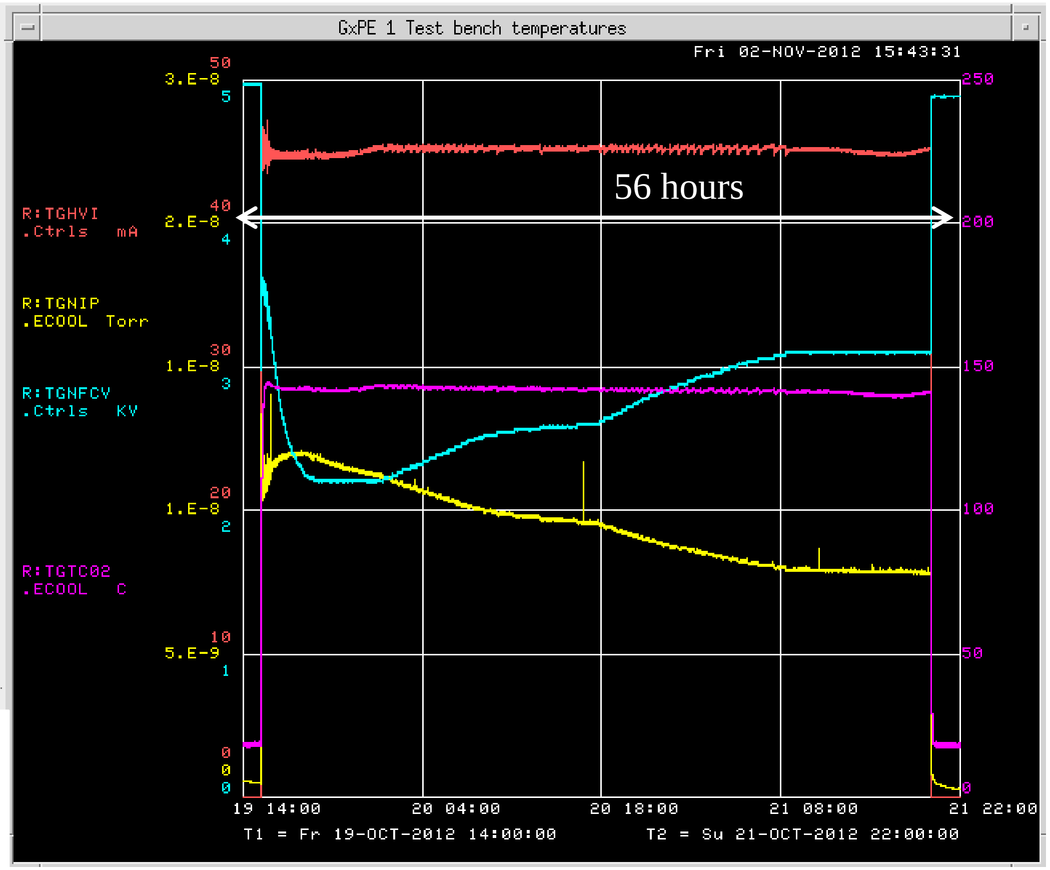


First beam at the absorber pre-prototype (18-Sep-2012): ~5.E-8 Torr/mA

Vacuum in the gun as a function of the beam current at the pre-prototype

- Limits the cathode emission
  - Started at < 1 mA
- Coefficient of outgassing dropped by ~500 times after long runs (days) of beam to the absorber
  - Estimation of the gas coming to the turbo: electron-stimulated desorption dropped from ~0.5 to~10^{-3} molecule/e
  - Likely comes mostly from surfaces irradiated by secondary electrons

Long runs: the tool to decrease outgassing



Beam current, 10 mA/div

Gun control electrode voltage, 1 kV/div

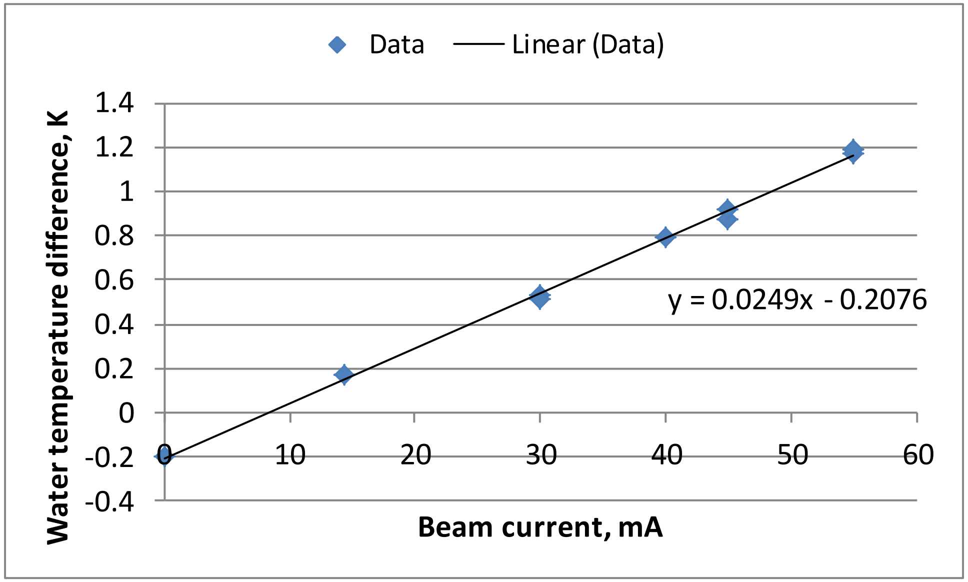
Gun IP pressure, 5 nTorr/div

TZM temperature, 50 C/div

Example of a long run at 45 mA.

- Program that regulates the current and monitors the pressure and temperatures (L. Carmichael, B. Hanna)
  - The gun control electrode voltage is adjusted to keep the current constant
  - Will use it for thermo-cycling tests

Power deposition



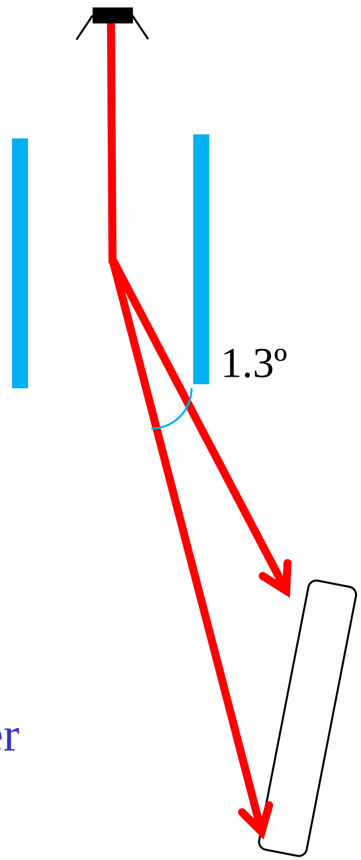
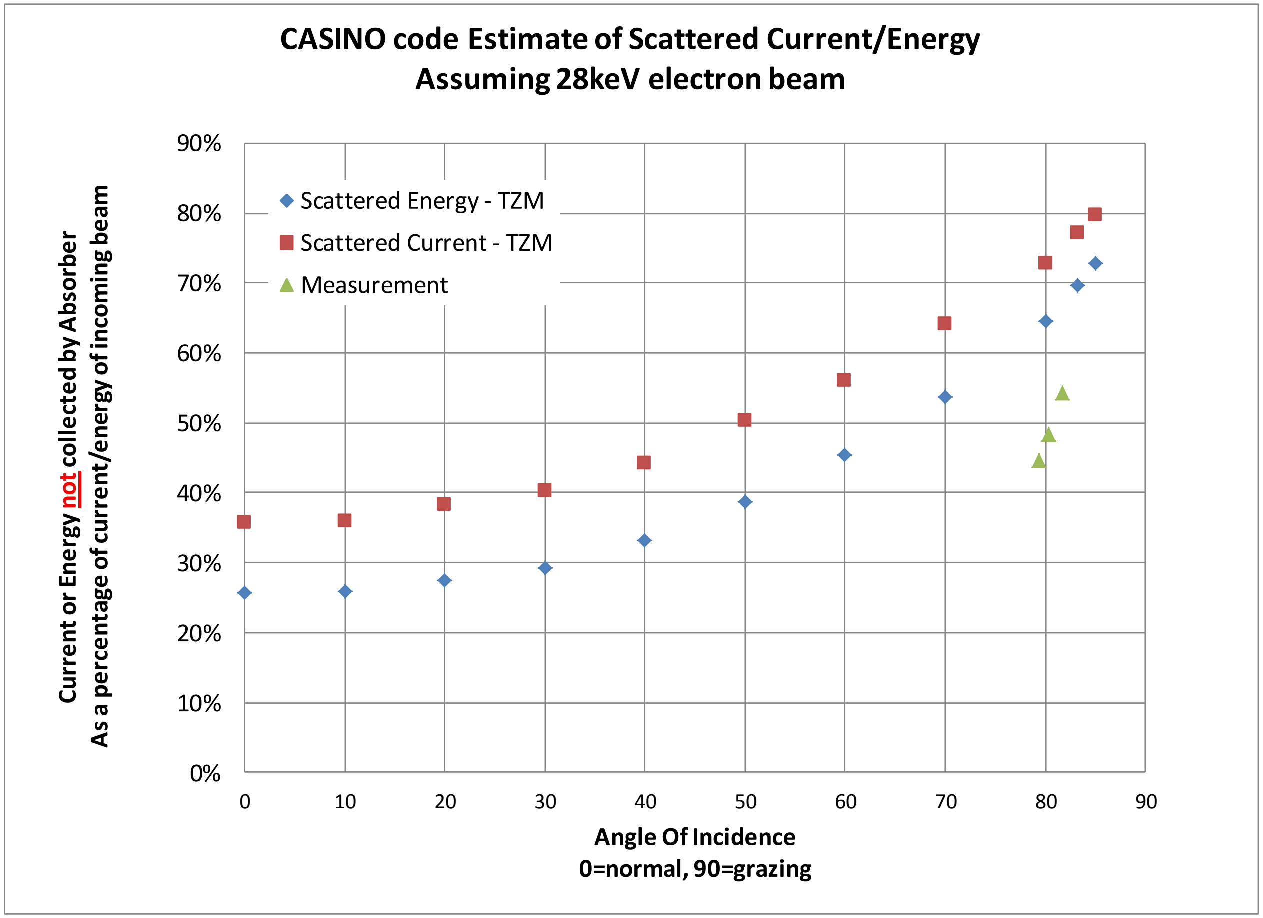


Illustration: the incident angle depends on the corrector current

- The inlet-to-outlet water temperature rise is linear with the beam current
  - With the water flow measured, the power removed by water can be estimated
- Only ~50% of the beam power goes to water
  - The reflection is so high because of a small grazing angle
  - Reflected power does depend on the grazing angle

Comparison with simulations

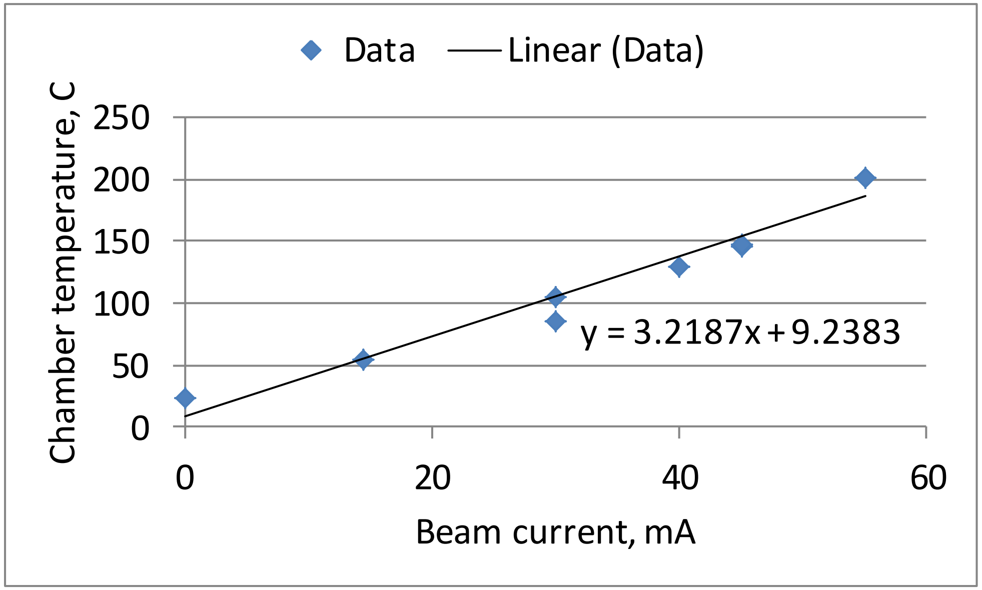


Measurements: portion of the power reflected from the absorber. The angle is calculated for the central trajectory.
1-Nov-12
55 mA, 28 keV

- Comparison of simulations and measurements of the reflected power
  - The measured reflected power is significantly lower than in simulations
    - Beam convergence angle is ~10 mrad; should have a negligible effect

Consequences

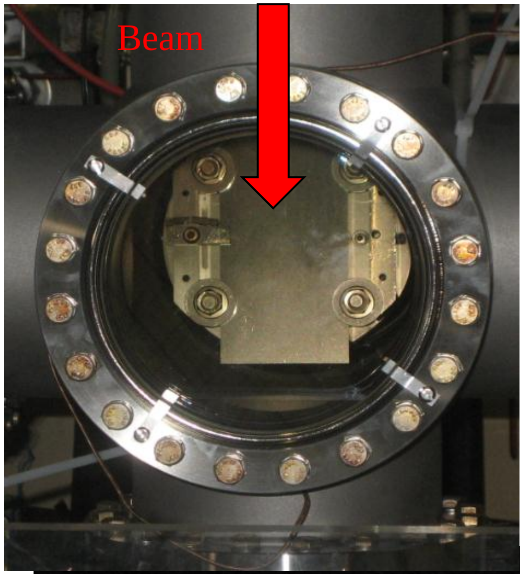
- Total power that can be deposited to the absorber is limited by the power supply and reflection to ~0.5* (200 mA * 30 kV) ~ 3 kW
  - Have planned to model 21 kW of H- with ~30% of power reflection
    - By increasing the grazing angle from 29 to 120 mrad
  - To model the power density, can increase the angle or/and decrease the beam size
    - Becomes less representative because of smaller longitudinal spot size
- Vacuum chamber is hot
  - Put a fan
  - Plan to install a blower



Temperature of the vacuum chamber downstream of the absorber as a function of the beam current.
16-24 Oct-12; 28 keV

Beam imaging

- The beam footprint can be measured by its Optical Transition Radiation (OTR) image
  - Randy Thurman-Keup set up a camera and a program
- Difficulties
  - At the beginning, a light from the residual gas
  - After a while, darkening of the glass
    - Likely, because of sputtering
  - Reflections and background
  - Thermal radiation
  - Camera saturation



View through the vacuum window at the beginning of the run with building lights are on and off.

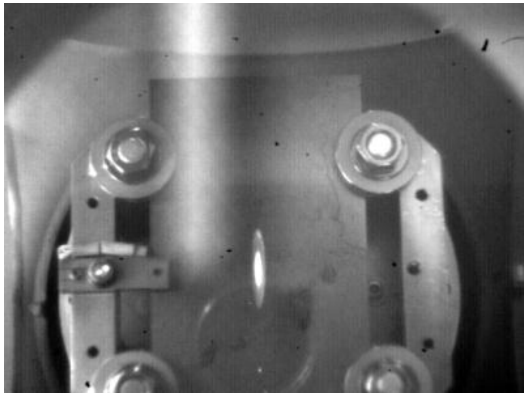
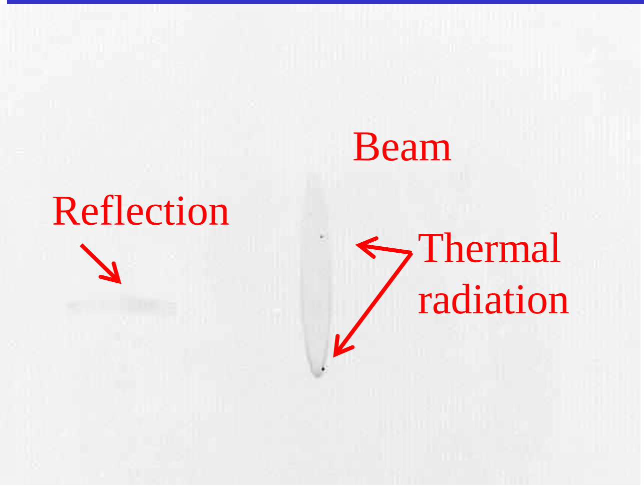
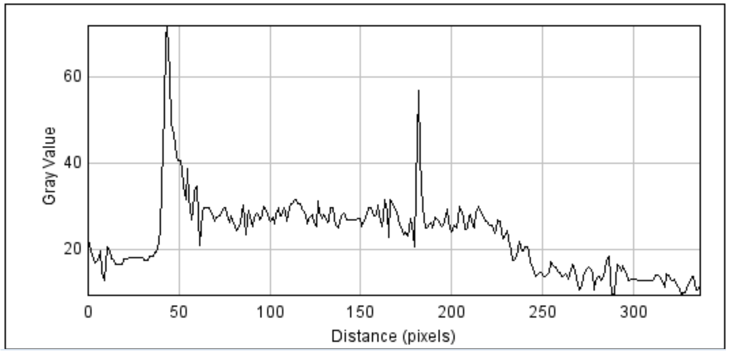
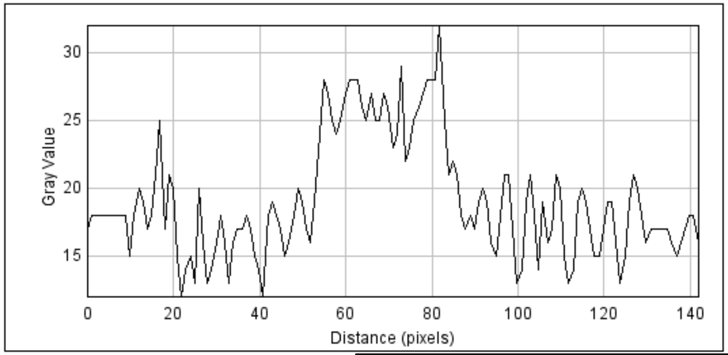


Image captured by the camera. Building lights are on. The beam current, 40 mA, is limited by emission.

Beam imaging: illustration of difficulties

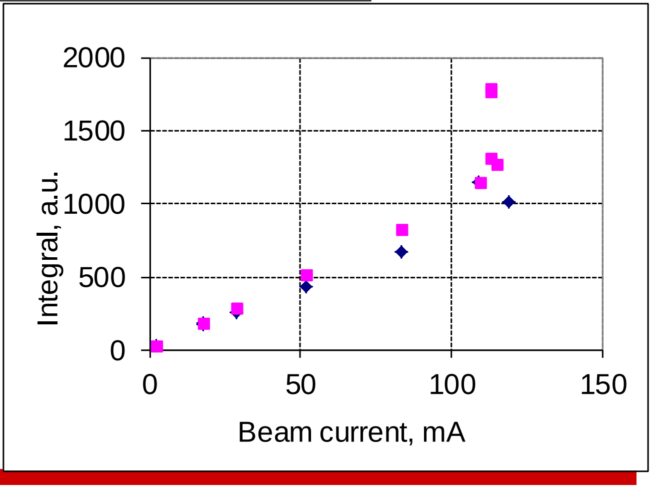






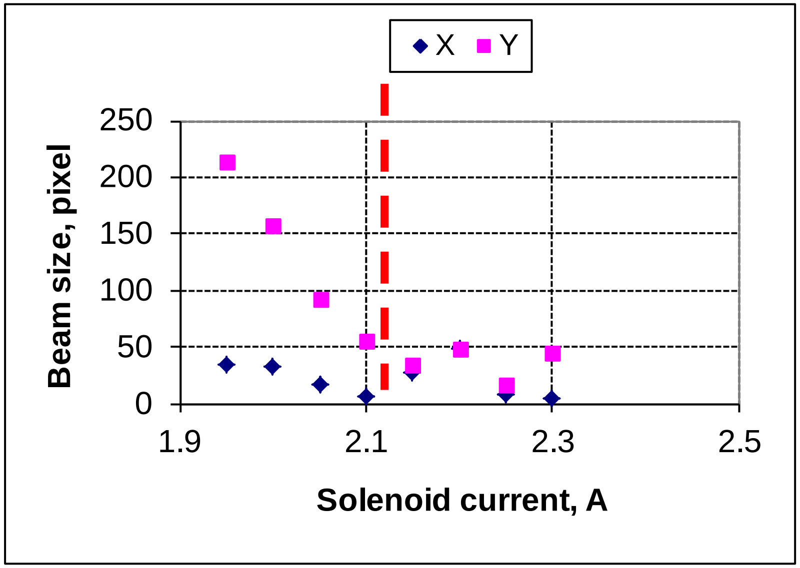
Distribution along main axes for the image. Axes are 203 X 31 pixels= 48.3X7.4 mm. The ratio, 6.5 corresponds to the angle of 8.7°.

Typical camera capture (negated for presentation purpose). 31-Oct-2012. 84mA, 28keV. The beam is under-focused (solenoid current = 2.0A). Background with no beam is subtracted (comparable in intensity).



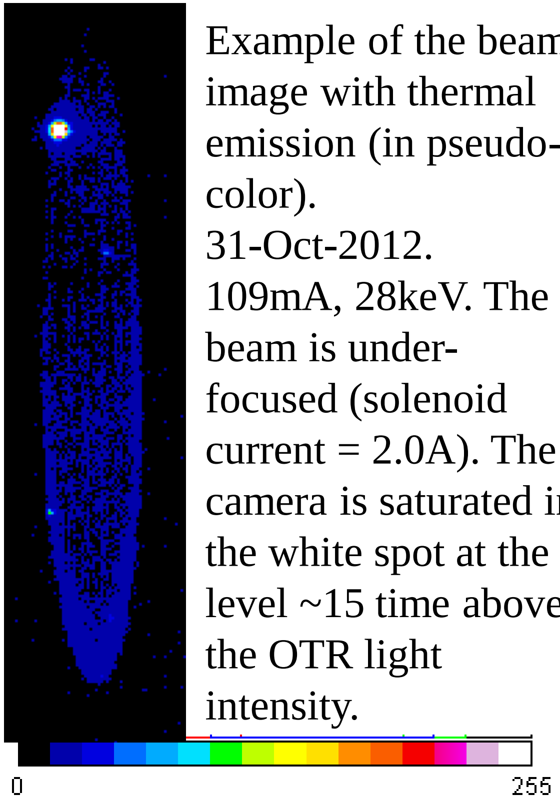
Integral of the light in the image as a function of the beam current for two currents of the solenoid. Integration frames are slightly different. Deviation from linearity corresponds to appearance of bright spots. 31-Oct-2012

Thermal radiation



Integral of the light in the image as a function of focusing (solenoid current).
28 keV, 52 mA. 31-Oct-2012.
At the solenoid current above 2.1 A the image is determined by thermal radiation.
10 pixels ≈ 2.4mm

- At any current where OTR is observable, there could be small bright spots, which locations change from run to run
  - Likely dust particles moved by the beam
- At a high current density, a bright, large spot at the very center of the beam footprint
  - Much less elliptical than the beam spot
  - Doesn't give a direct information about the beam size



Example of the beam image with thermal emission (in pseudo-color).
31-Oct-2012.
109mA, 28keV. The beam is under-focused (solenoid current = 2.0A). The camera is saturated in the white spot at the level ~15 time above the OTR light intensity.

Present capabilities

- The electron beam can be focused into a size comparable with that expected for the PXIE H- beam at absorber (~2 mm rms radius).
- Can run for days at 60 mA (at the nominal filament current)
  - Running at higher currents is limited by cathode poisoning in ~hour time
- Minutes- long “pulses” can be at >120 mA
  - Limited by the present administrative limit of 150 mA
  - Should be good enough for thermal-cycling tests at full beam power
- Could measure the beam size of 0.3 sec pulsed beam by passing it through a hole
  - The plate is damaged and needs a replacement
- At a low power density, the beam size can be measured with OTR
- Can observe an onset of thermal radiation
  - Need more work to separate reliably between dust particles and a bulk
  - Likely indication of reaching ~900 C

Summary

- The electron beam test bench has been commissioned and is ready for testing of the absorber prototype
  - ➢ The tests can be performed at various beam focusing parameters
    - To represent better either the local power density or a long footprint
- Lessons
  - ➢ The vacuum chamber of the final absorber requires serious considerations because of the large reflected power and current
  - ➢ Using OTR images for H- beam may be difficult
    - Lower output, light from the residual gas, thermal emission
  - ➢ Moving a dust by the beam could be a problem
- Side benefits
  - ➢ Have a simple beam stop tested to ~1.5 kW of deposited power
- Plan
  - ➢ Hope to start testing the prototype in December 2012
  - ➢ Before that, reach ~200 mA at the absorber and test a thermo- cycling procedure