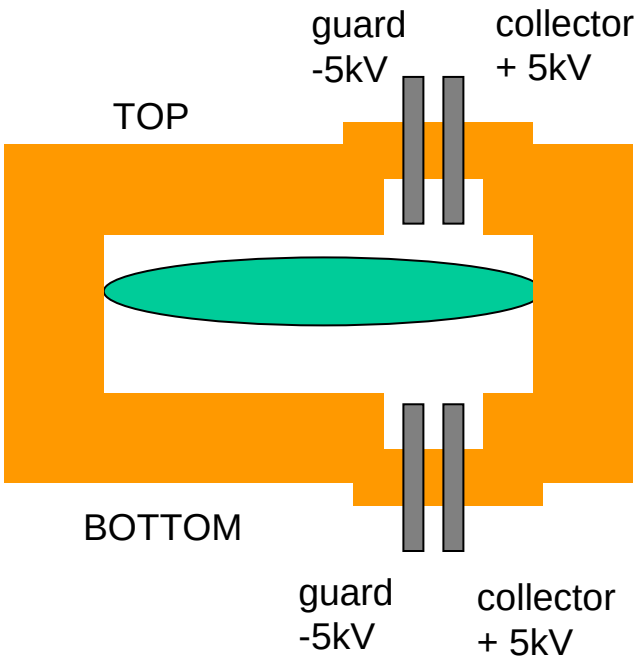
Video-based X-Ray Beam Position Monitoring at CHESS

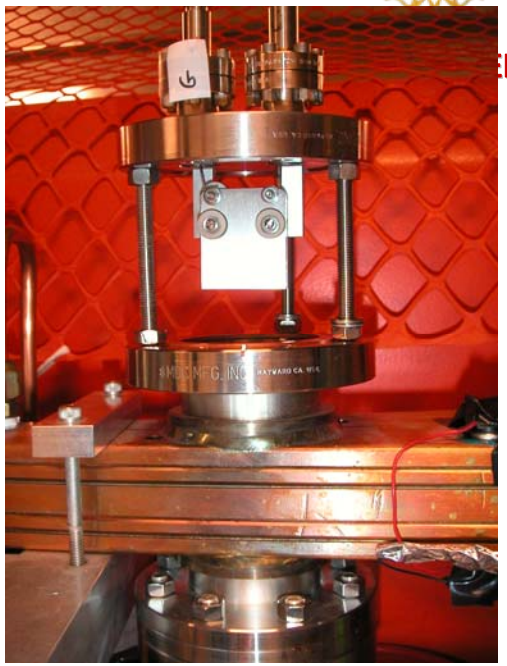
Peter Revesz, Cornell University, CHESS
Ithaca, NY 14850

Basic Types of XBPMs:

Intercepting	barely intercepting	non-intercepting
Most fluorescent screens	photo-electron types wires lateral photo-diodes	Gas luminescence

Photo-Electron Beam Position Monitor for CHESS wiggler beam lines





Disadvantage:

Measures the fringes only:
Hard bend contamination.

Benefits:

Fast, robust, reliable

Possible problems:

Linearity?

$T=\alpha I_o x+\beta$,
$B=\alpha' I_o(1-x)+\beta'$

For symmetrical and linear detector:

$x \sim D/S=(T-B)/(T+B)$

The Classics form 2002
VBPM exhibition at G-line

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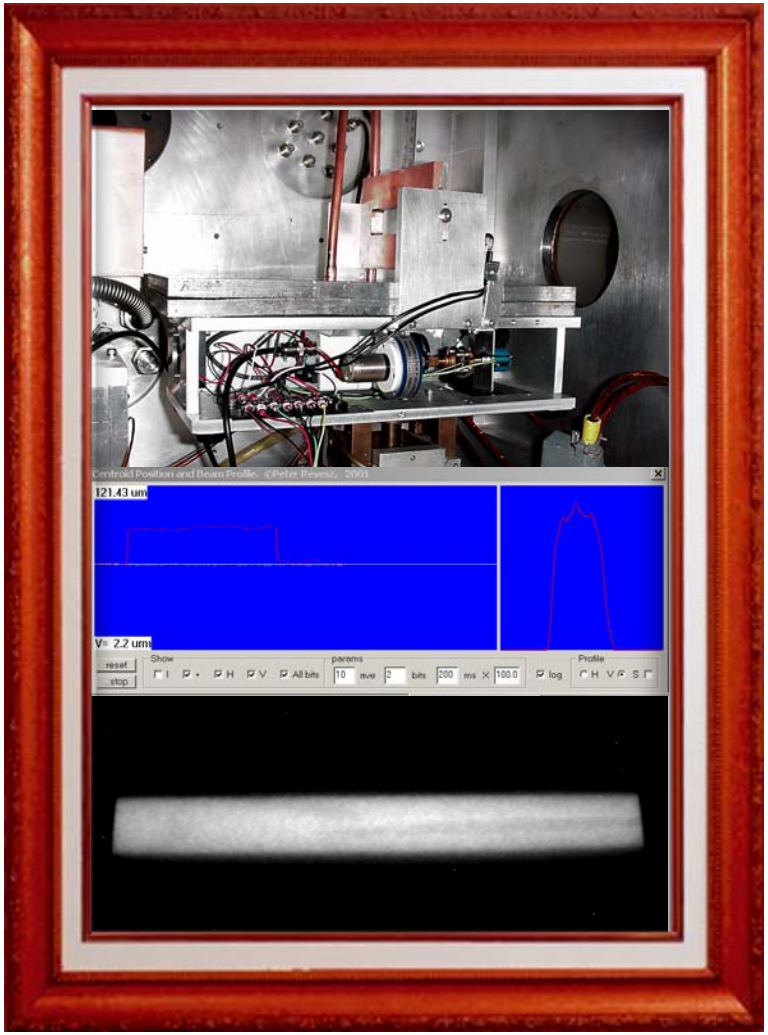
He gas luminescence



Diamond screen

The Principle of VBPM

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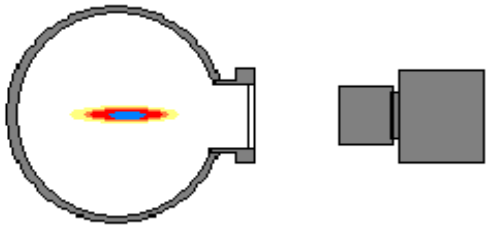
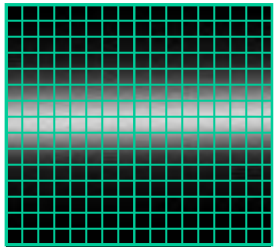
Camera setup

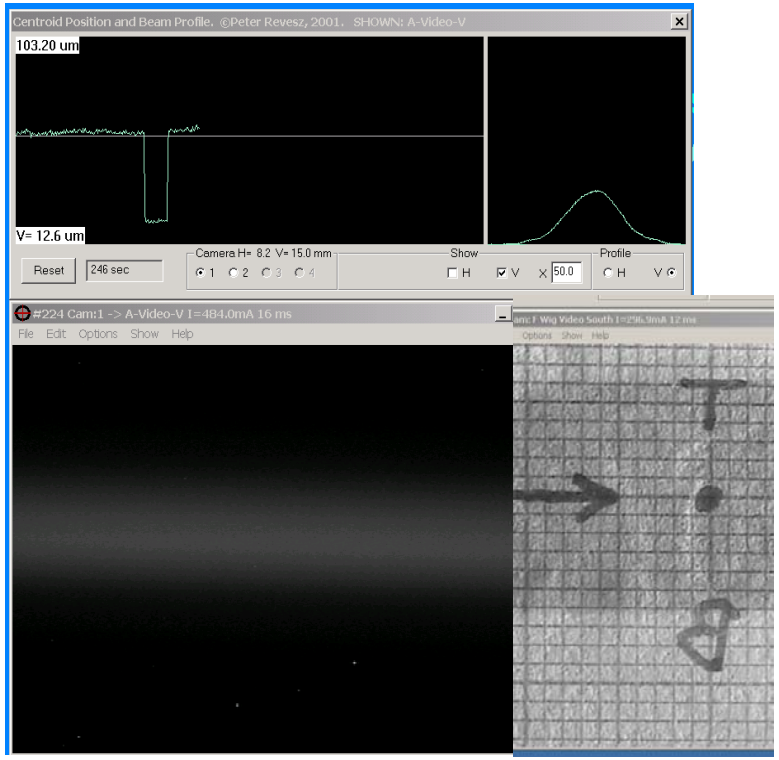


Captured image



Centroid position

$$Xc := \frac{\left[\sum_{(i,j)} i \cdot G(i,i)\right]}{\sum_{(i,j)} G(i,j)} \qquad Yc := \frac{\left[\sum_{(i,j)} j \cdot G(i,i)\right]}{\sum_{(i,j)} G(i,j)}$$



Xc and Yc in pixels, but
It is easy to cross-calibrate to microns by imaging a mm-grid.

No Z-jack is needed, the whole system can be mounted rigidly.

It is not just a “number” but visual information as well. Important also as a diagnostic tool.

Advantages and Disadvantages of VBPMs

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PRO

- Non-intercepting
- Visual information
- Position is basically what the user has
- Provides beam profile
- No Z-jack needed, easy calibration
- Beam size information
- Beam intensity information

CON

- More complicated H/W
- Requires special software
- Requires computer
- For analog cameras: noise creates artifact beam motion
- Non-vacuum
- Possible radiation degradation
- “Zingers”

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How sensitive is the centroid measurement?

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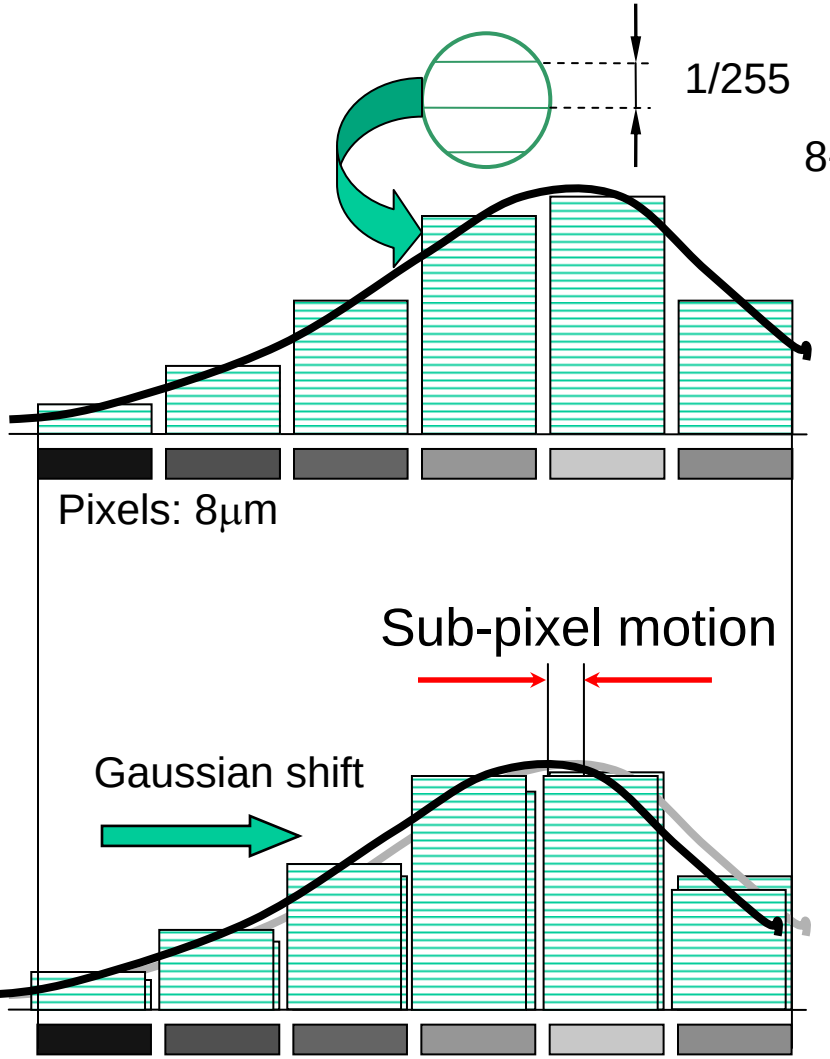
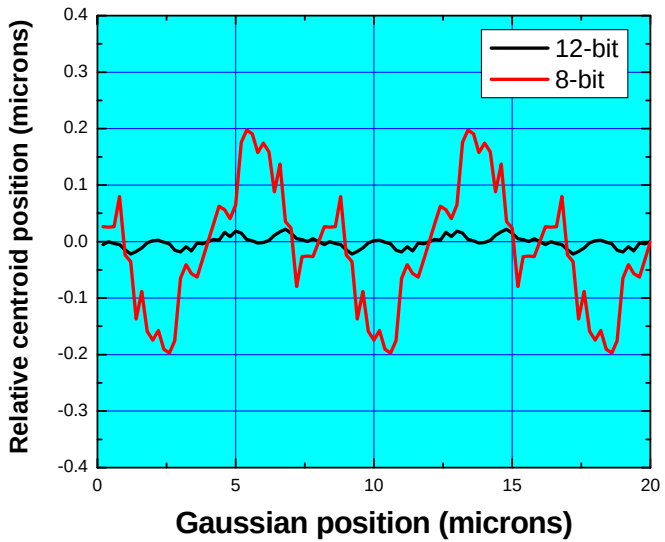


8-bit digitalization: 255 Grayscale steps

Computer simulation



Bench test of centroid position sensitivity

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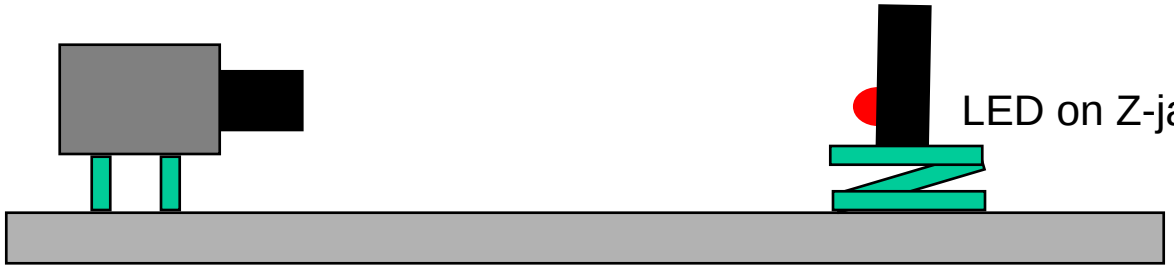

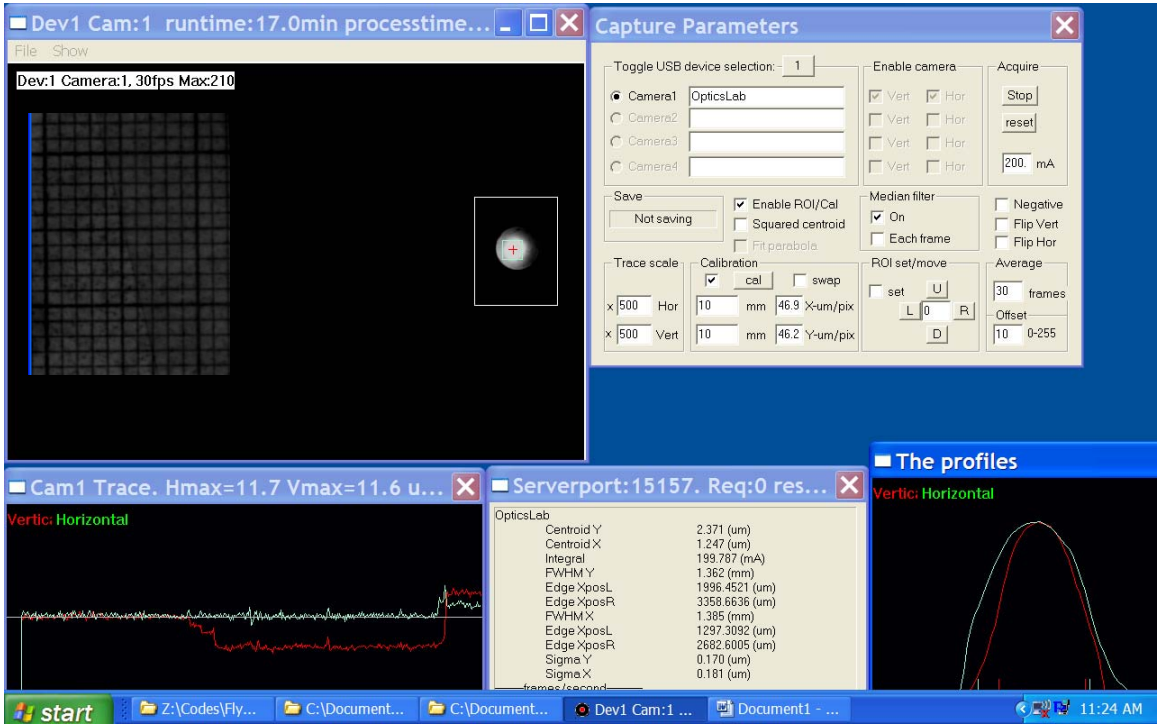

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Linearity and Offset

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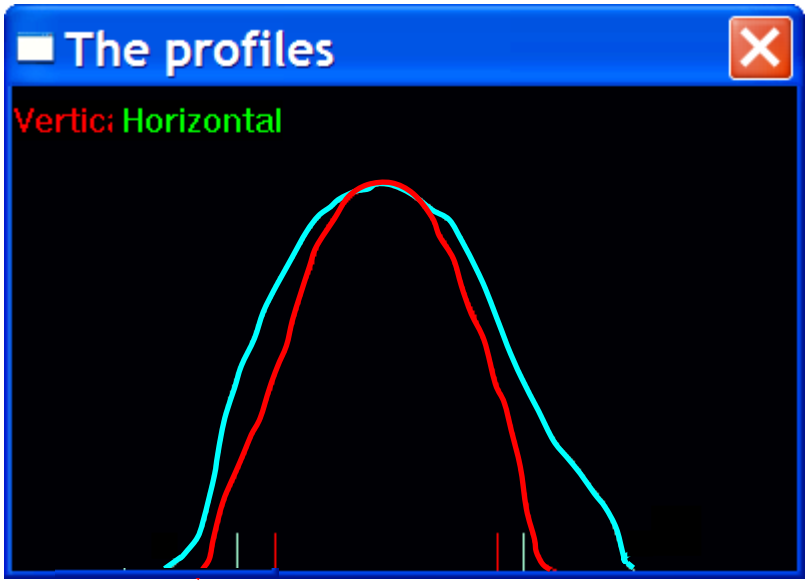

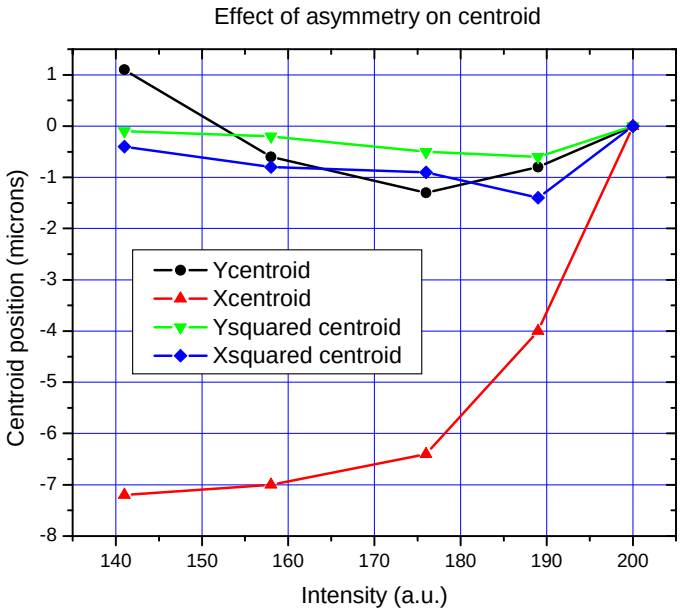

The use of squared centroid helps to reduce the artifact due to offset an asymmetry

Squared centroid : $x_{sqc} = \frac{\sum x \cdot I^2(x,y)}{\sum I^2(x,y)}$

-Helps to reduce the effect of offset for asymmetric profiles.

VBPM program and architecture

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Beam lines Analog cameras, Sensoray 4 input USB 2.0 frame capture devices

Camera/Image control
For multiple cameras:
- Enable/Disable cameras
- Set ROIs
- Adjustments:
  Brightness, gain, offset, averaging
- Calculate:
  centroids, Intensity, FWHMs, edges

Display:
  Image, centroids, trace, profiles

Calibrate:
  Pixel-to-micron
  Intensity-to-mA

Frame Capture:
- Get pixel data in ROI
- Adjustments:
  median,
  rotation, flip
- Calculate:
  centroids,
  Intensity,
  FWHMs,
  edges
  standard deviations

Display:
  Image, centroids, trace, profiles

Communicate:
- Accept UDP connection from server
- Accept and respond to:
  SENDALL
  LISTALL and
  SENDBYNAME
- Send data

VBPM Centroid program user interface

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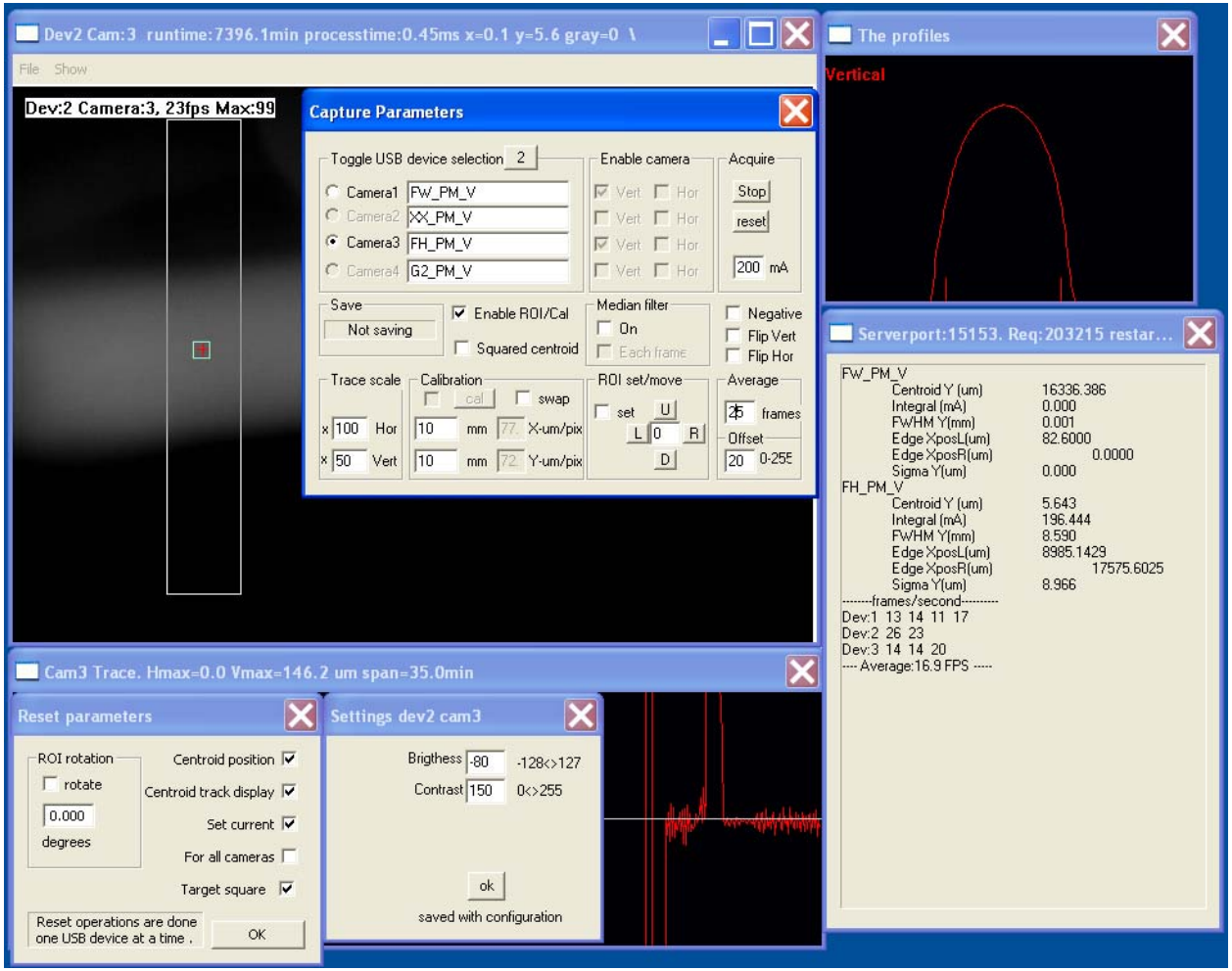

Allows to control 12 cameras,

Allows operator to visually inspect all camera images to optimize settings,

Transmits positions, width, intensity to signal collector program,

Saves data, Saves/retrieves system configuration

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CHESS-East Position monitors

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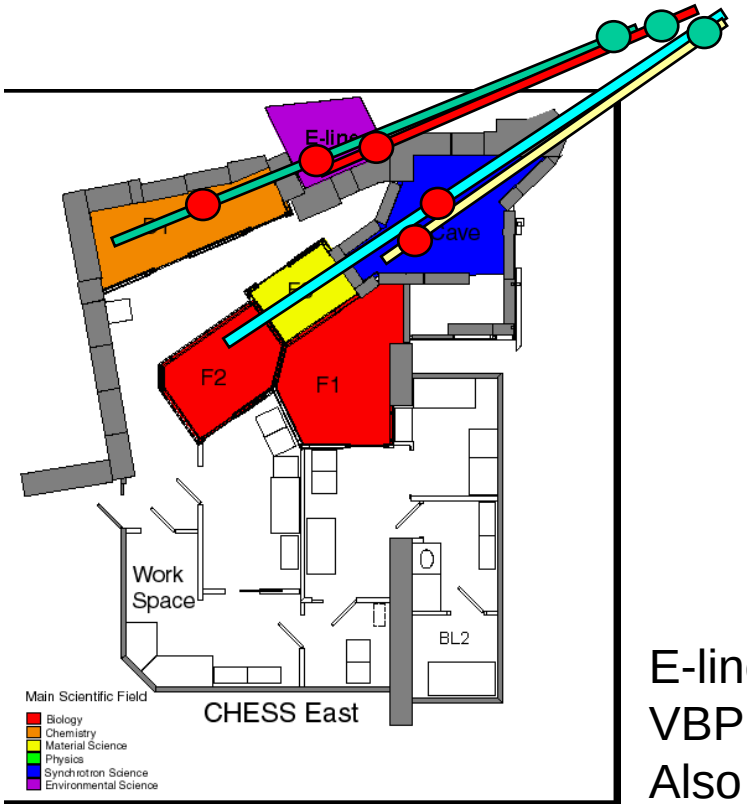
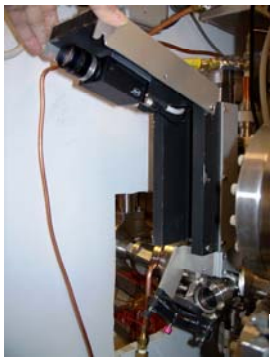
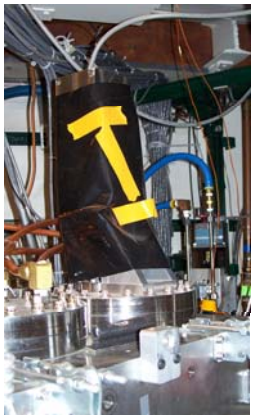
- VBPM
- P.E



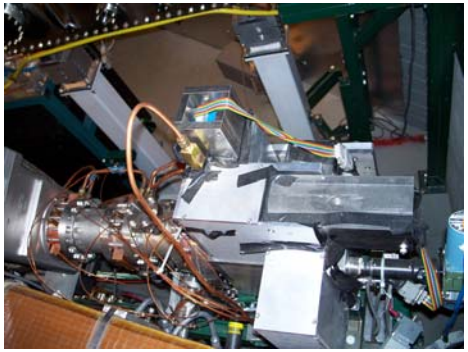


D-line diamond VBPMs in tunnel And cave

F1-F3-line He VBPMs in cave



E-line He VBPM in tunnel Also source size measurement



CHESS-West Position monitors

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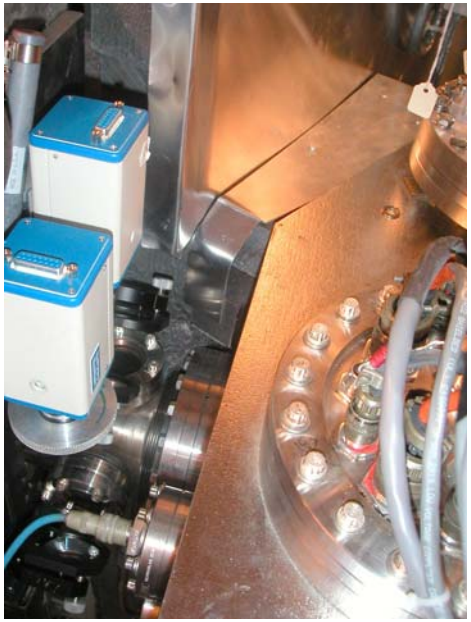
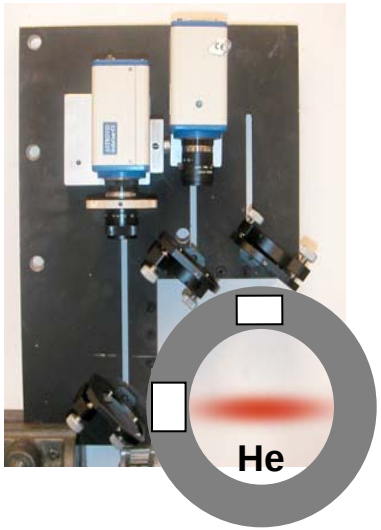
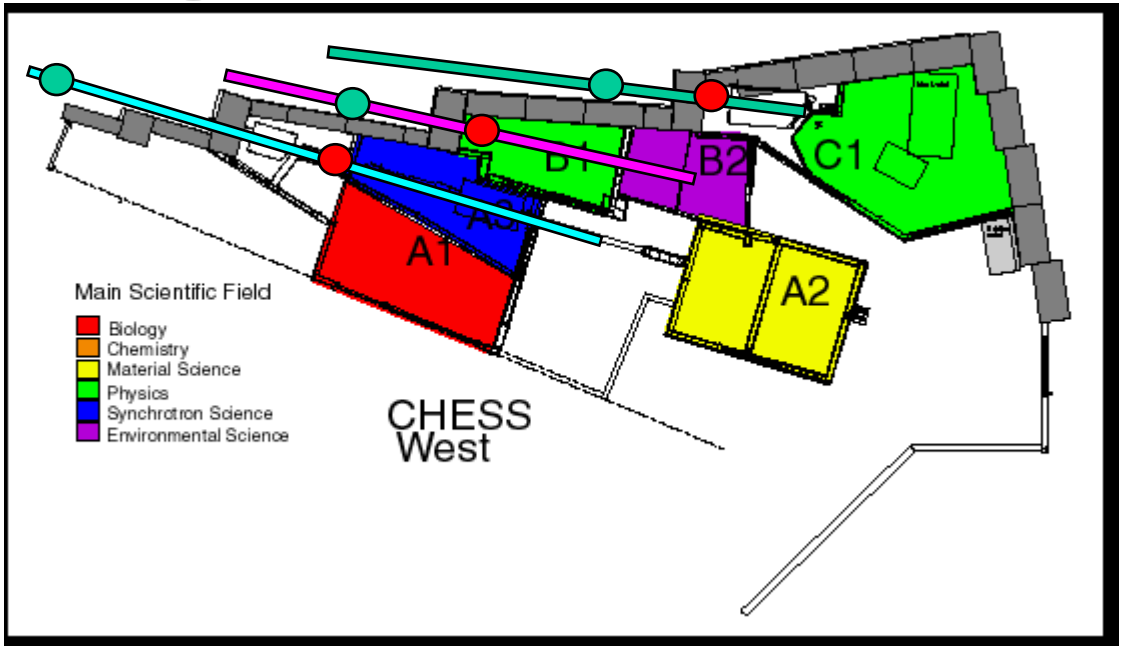




- VBPM
- P.E



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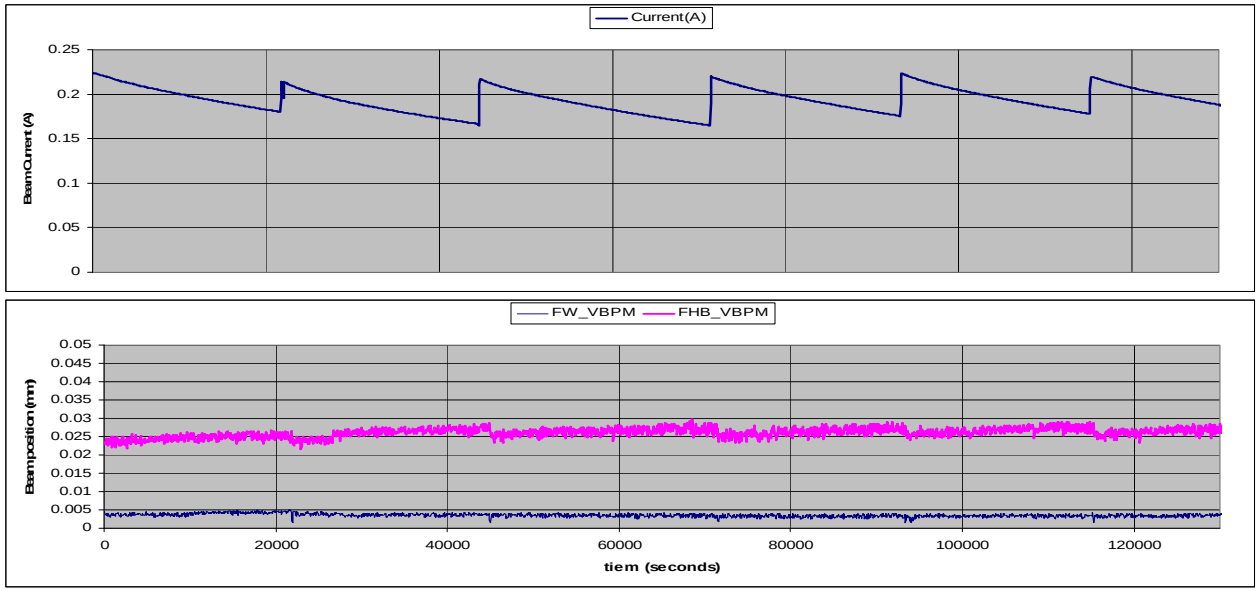

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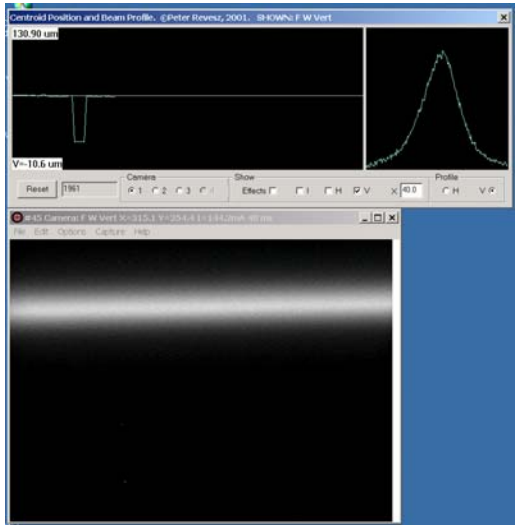
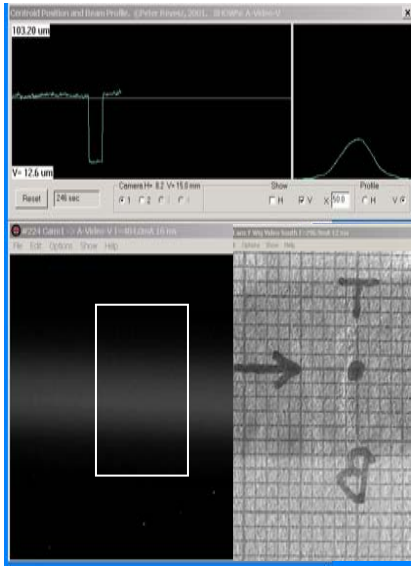
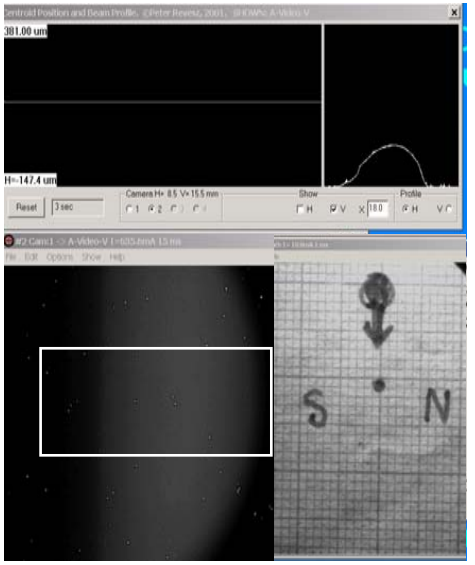


F-W_VBPM



A-Ver_VBPM



A-Hor_VBPM

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CHESS-G-line Position monitors

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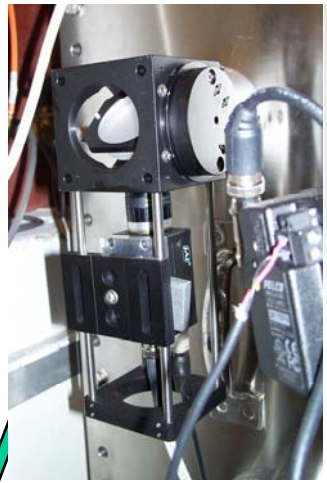
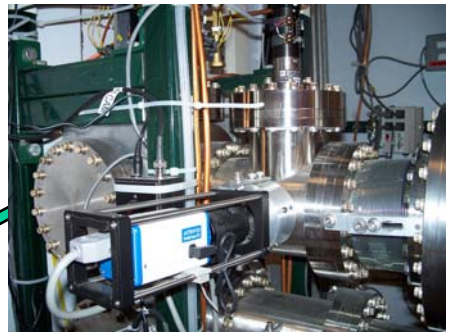
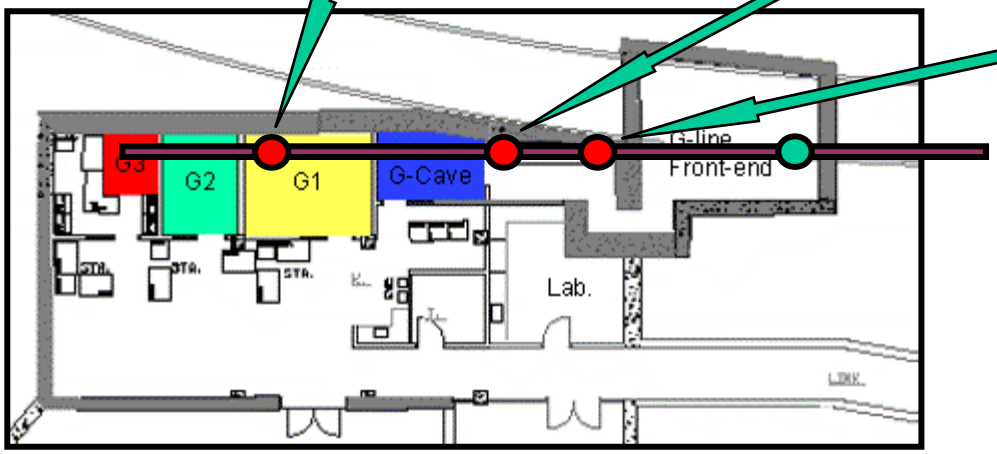
- VBPM
- P.E







CHESS-G-line Position monitors

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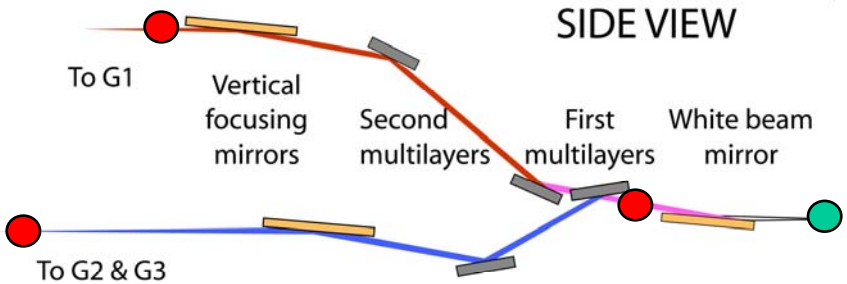
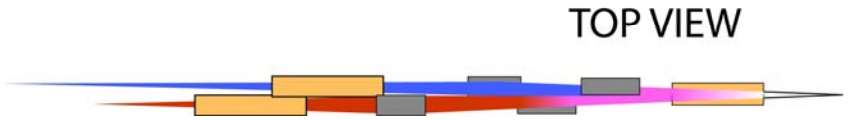
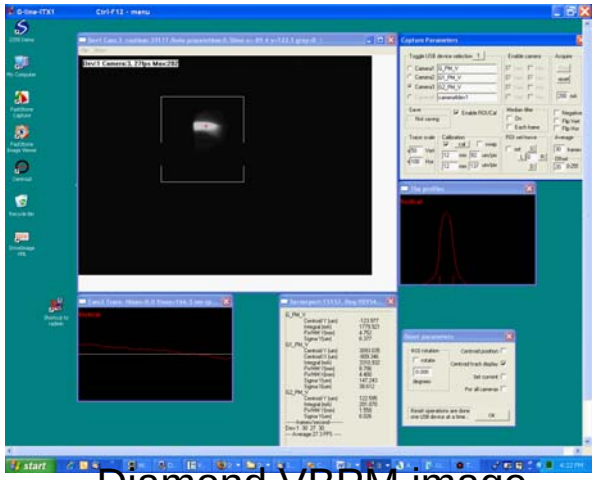
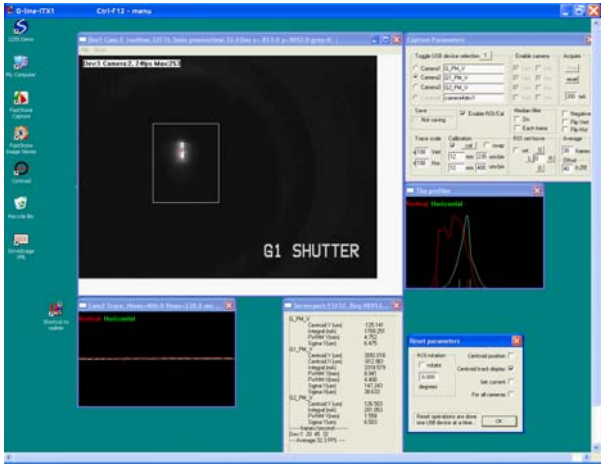


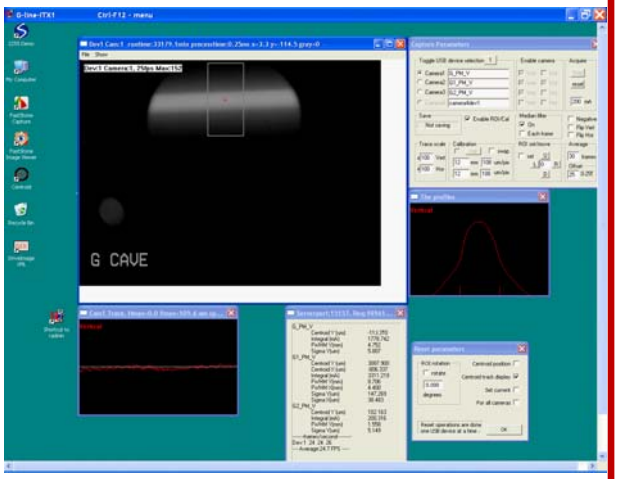




Diamond VBPM image at G2 beam passed multilayers and focusing mirrors



Diamond Video BPM image at G1 shutter location (passed multilayers and focusing). Spill-over is seen.



The Video BPM image of He-luminescence at G-cave. Here beam reflected from the mirror upstream is shown.

G-line position signals

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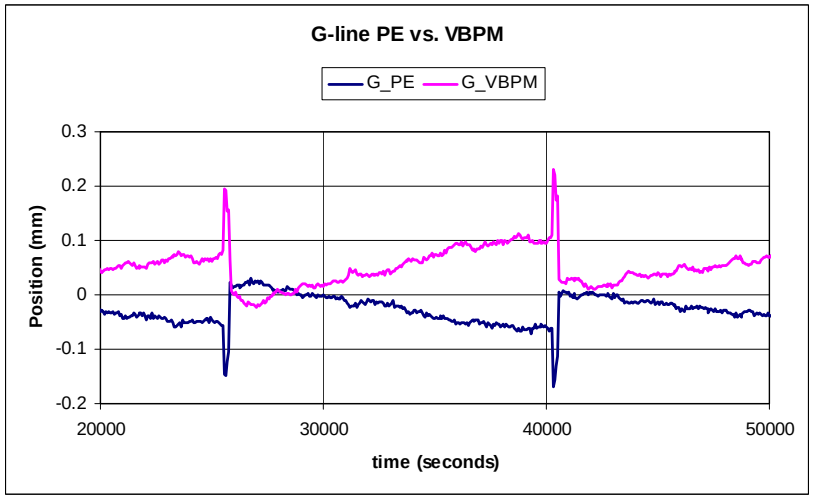

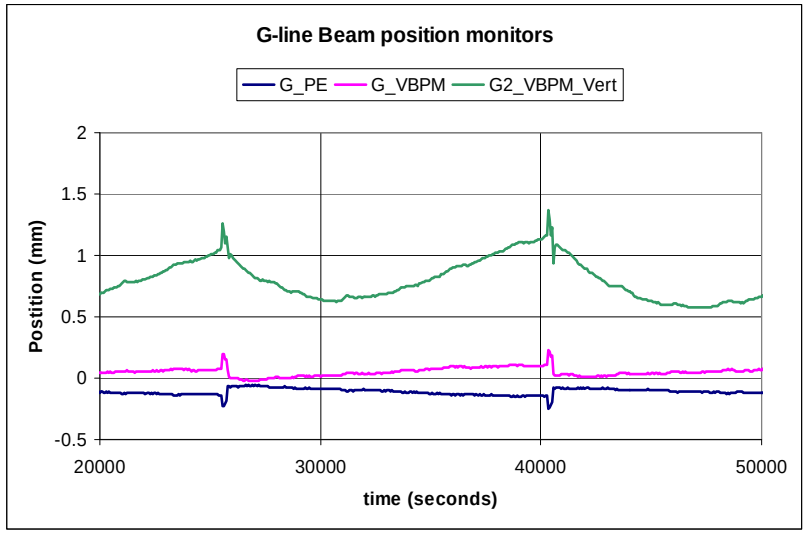

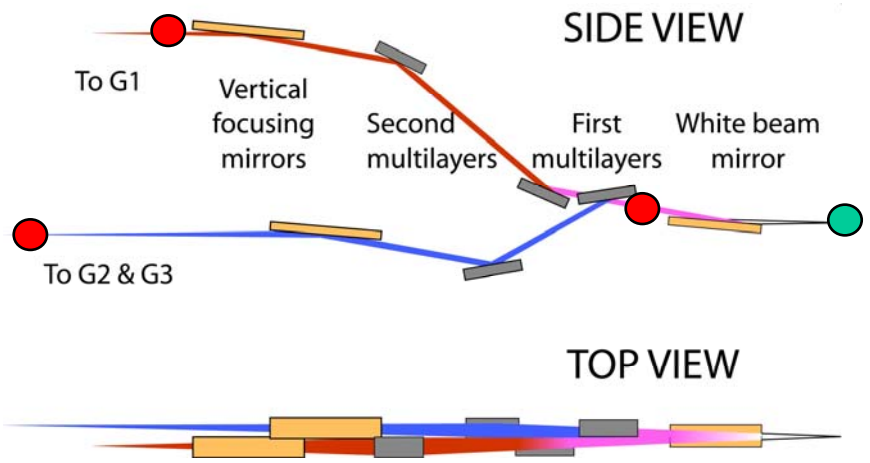

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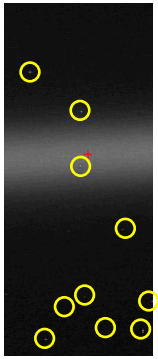
Some VBPM pitfalls

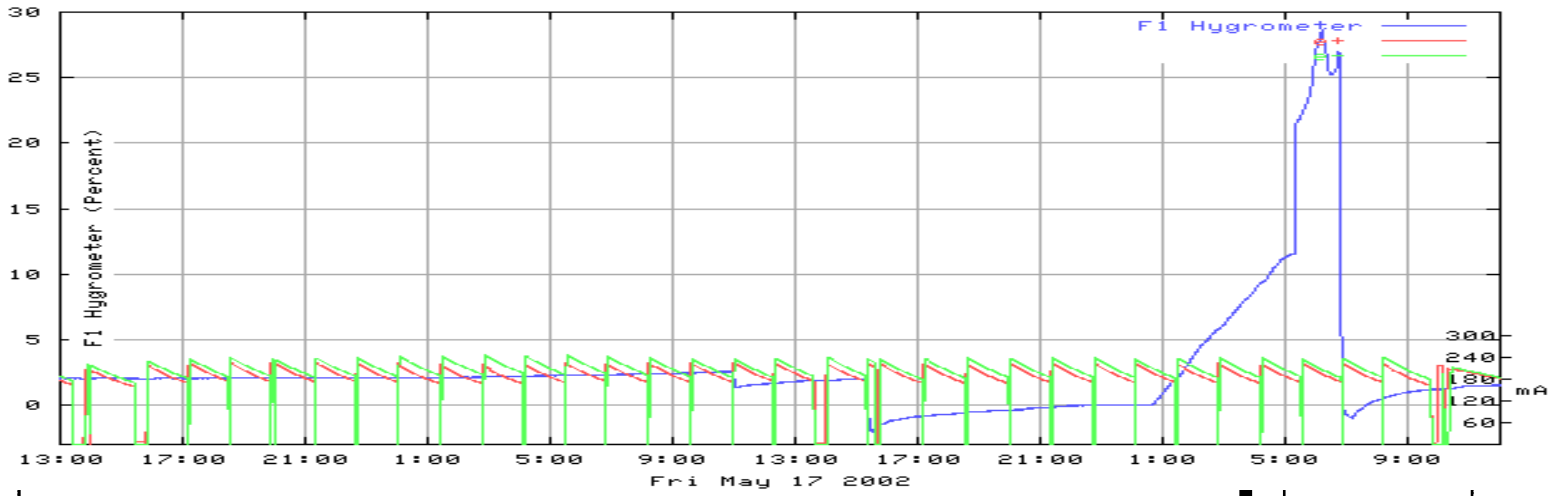


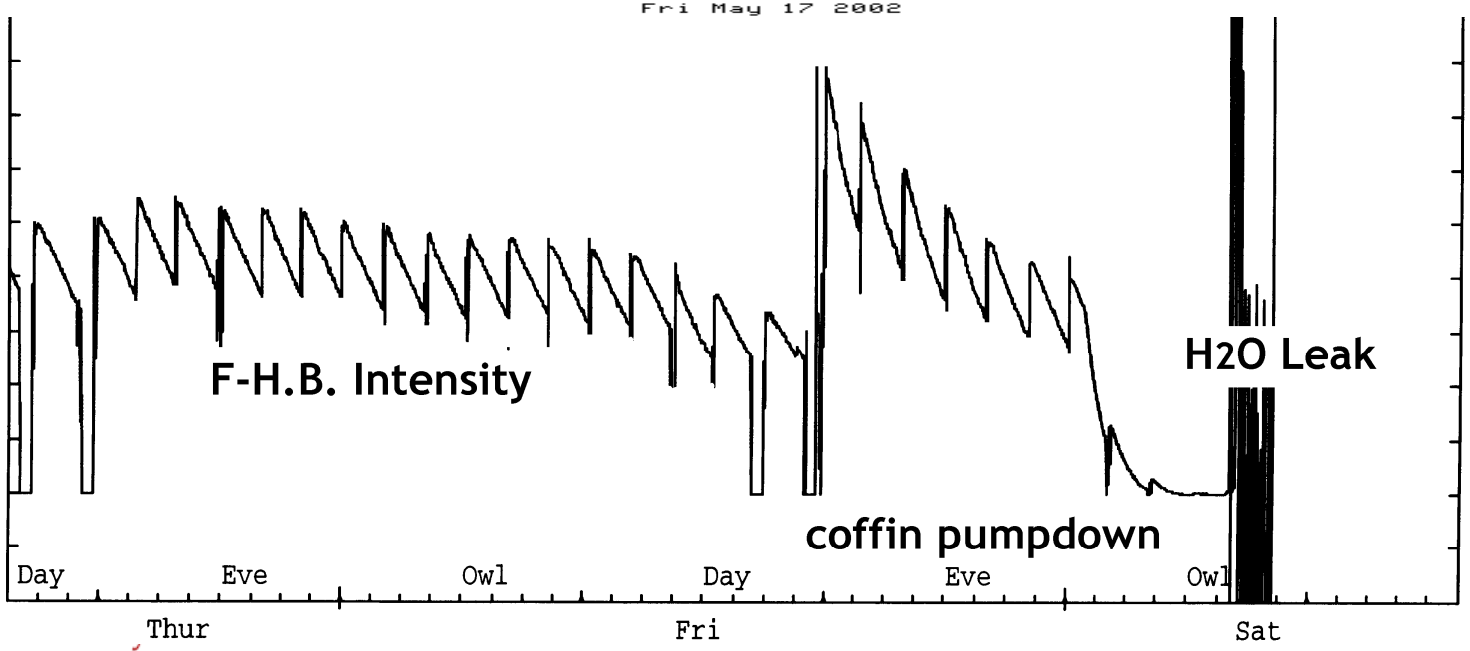
- Offset effect on position
- Noise and ground-loops
- “Zingers”
- Intensity saturation
- Contamination, humidity

To minimize these effects:

- Eliminate background light, adjust offset
- Short video cables, filters and video amplifiers, ultimately use digital camera
- Image filtering i.e. median, shilding
- Optimize optics, shutter time.

Humidity effects He luminescence !





Conclusion and Summary

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Video BPMs give multitude of important operational information about X-ray beam conditions.

The future:

Application of intelligent cameras, where the frame processing is inside the camera with built-in FGPA and DSP. This will reduce noise, the network data traffic volume and make possible faster frame capture.

references

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An X-ray beam position monitor based on the photoluminescence of helium gas
Nuclear Instruments & Methods in Physics Research, Section A **540, n 2-3**, 470-9 (2005)

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