Prototype OTR Design Review

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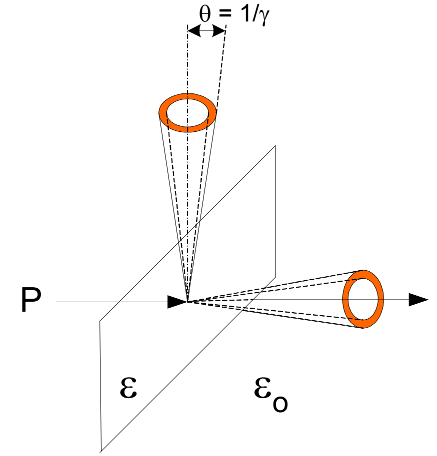
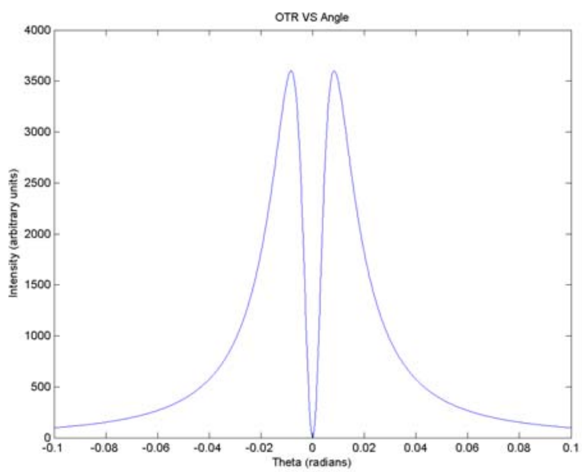
Optical Transition Radiation (OTR) Physics

- Optical radiation in cone peaked at $\theta = 1/\gamma$
  - light ~ uniform in ω
- Use backward OTR signal
- Backward OTR at specular angle
- Quantity of light proportional to foil reflectivity
- Thin foil to minimize beam scattering





Fermilab OTR Prototype Goals

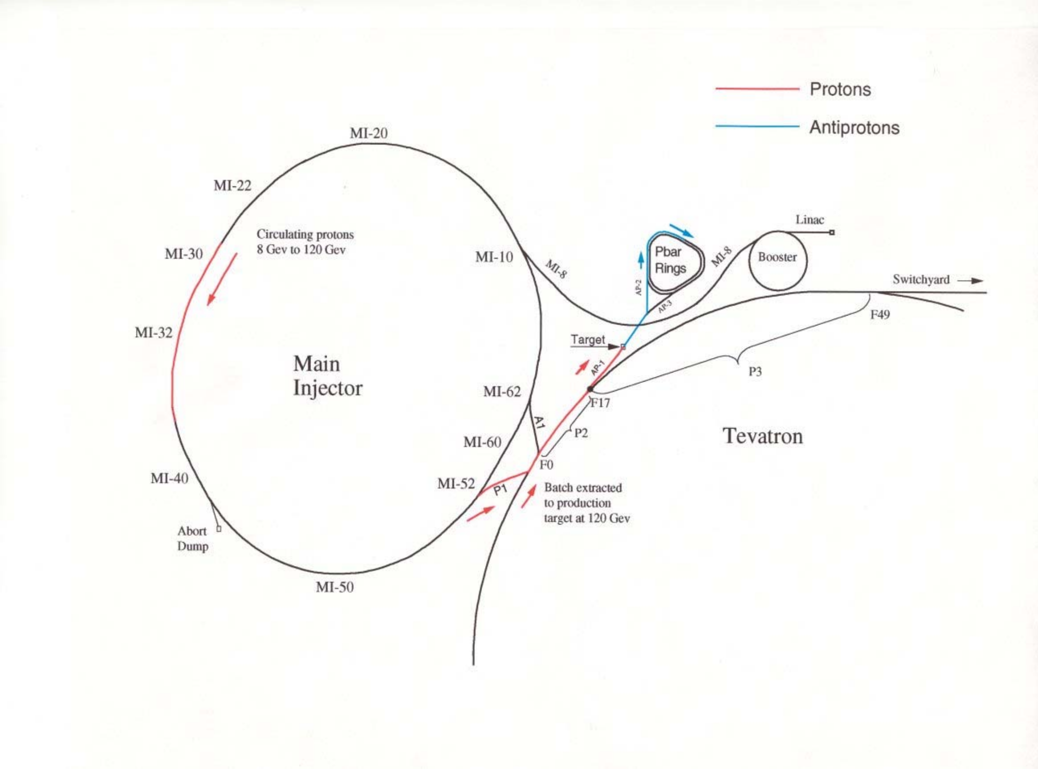
- Learning tool for transfer line OTR detectors
- Identify physics and operational issues
- Test of materials
  - Foil types – Aluminum and Titanium
  - Lenses – singlets, compound and quartz
    - Study of radiation damage to lenses
- Test of imaging
  - Development of single frame acquisition
  - Image noise analysis
  - Beam position and shape analysis
    - Calibration techniques
- Test of radiation environment

Location Requirements

1. Easy access
2. Location available early
3. High beam duty cycle
4. High energy beam – minimize OTR light cone
5. Large number of particles per batch/bunch
6. As low as possible radiation environment for camera and optics

Prototype OTR Location – Prevault AP1 Line

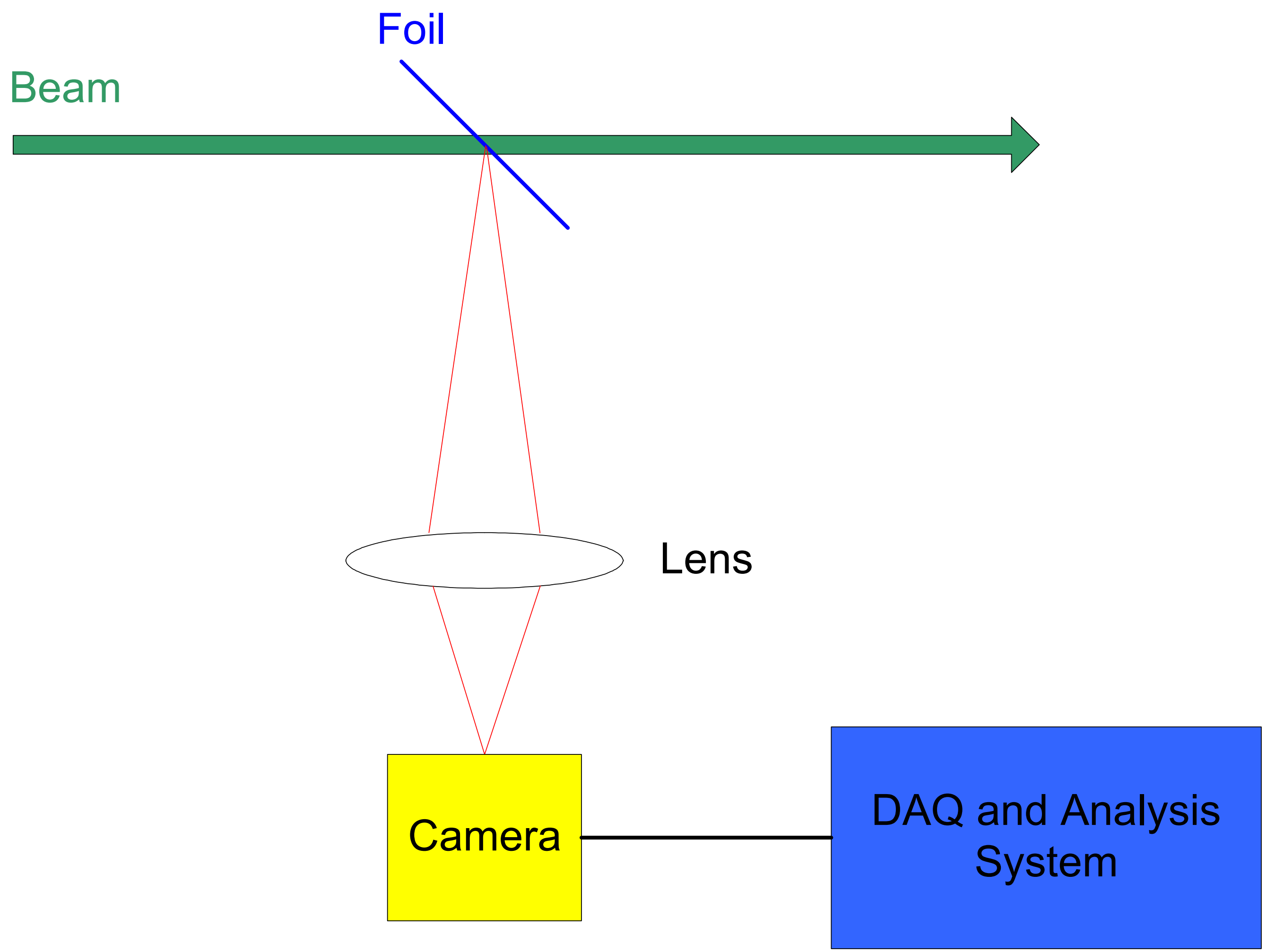
- Fairly frequent access to location
- Location immediately available
- Frequent beam- stacking
- High intensity – 4e12
- High energy – 120 GeV
- *High radiation environment?*



Prevault

- OTR placed in 9" air gap
- Titanium windows up and down stream
  - OTR and radiation source

Simple OTR Detector



Foils

- 20 μ Aluminum and 12 μ Titanium
  - Thinner foils available
- Aluminum brighter than Titanium
- Titanium stronger; higher melting point
- Choice of foil dependent on particle flux
- Test both in prototype system
- Other possibilities?
  - Carbon
  - Aluminum evaporated on titanium
    - Strong and reflective

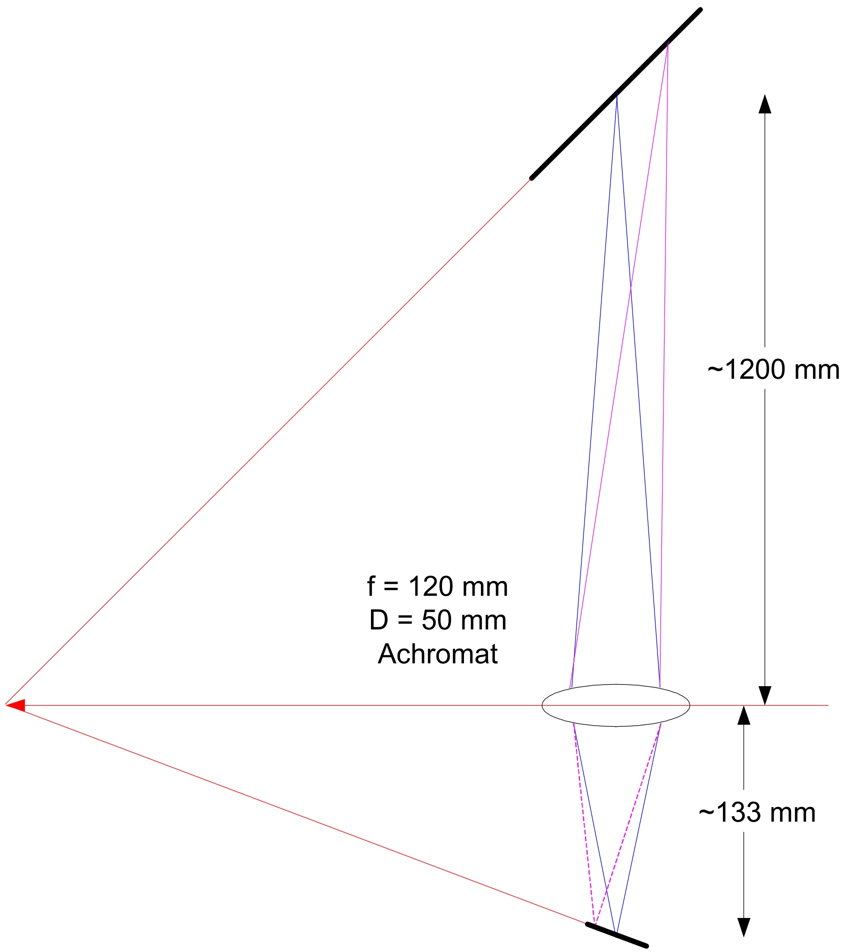
Cameras and Lenses

- CCD vs CID
  - CCD: best image quality but *very* radiation sensitive
    - Won't use CCD in Prevault area
  - CID: fair image quality, darker image, radiation resistance (~ 1 Mrad)
- Quartz vs Optical Glass
  - Optical glass: best image quality, off-the-shelf, radiation sensitive (darkens ~ 10 krad)
  - Quartz: radiation resistive, limited image quality

CID Camera

- Radiation hardened RS-170 format camera
  - 1e6 rads total dose (gamma)
  - 786 x 612 pixel format
  - 11.5 x 11.5 μ pixels
  - 30 frames per second
  - 47 db signal-to-noise ratio
  - ~35% quantum efficiency
  - Spectral response peak ~ 550 nm

Single Lens Optical Design



- Minimize radiation damage by placing camera/lenses far from radiation source
  - Distance to lens ~ OTR width ~ lens size
- Use achromatic doublet
  - Minimal glass
- Magnification = 1/9
- Field of view ~ 80 x 55 mm
  - ~ 100 micron per pixel
- OTR pattern ~ $4/\gamma$
  - 40 mm wide at lens
- For best focus, place camera at Scheimpflug angle

Off-Axis Beam Issue

- System aligned for beam at optical axis
- Off-axis beam reduces light received by lens
- Need to recenter optical axis to beam axis
  - Danger of obstructing beam
- Tilt foil in θ & ϕ to recenter light on optical axis
  - Tilt is small; < 2 degrees

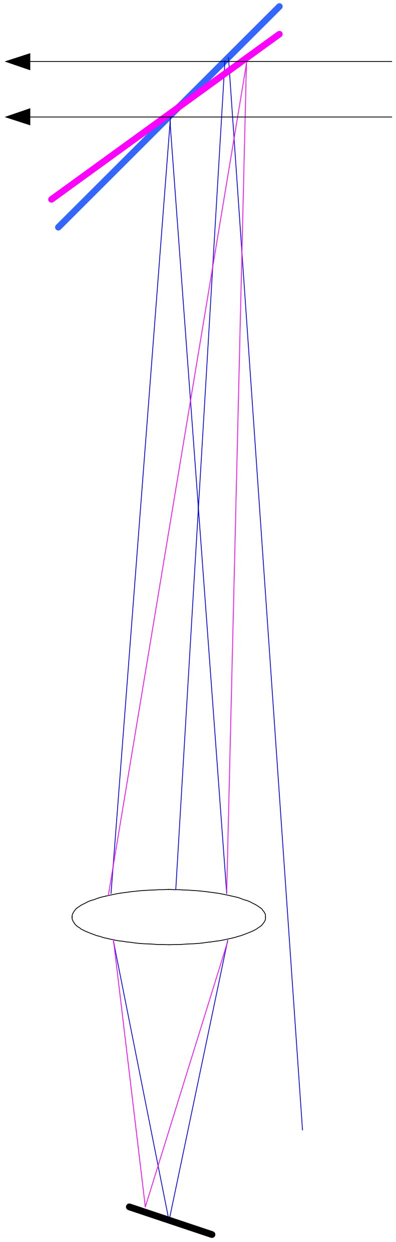
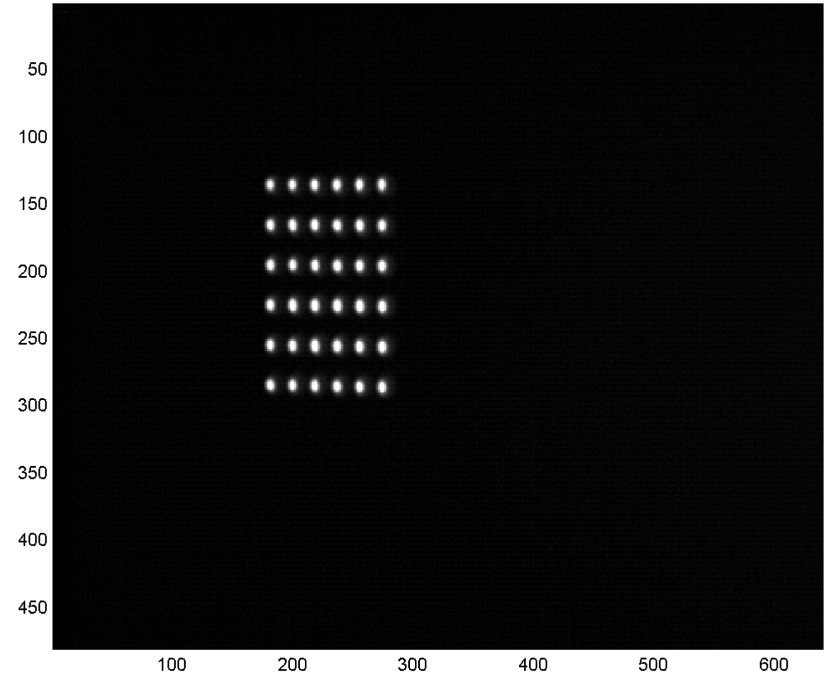


Image Resolution

- Image resolution low
- Point Spread Function appears to have $\sigma \sim 1.5$ pixels
- Can deconvolve PSF for sharper image
- Need of further investigation

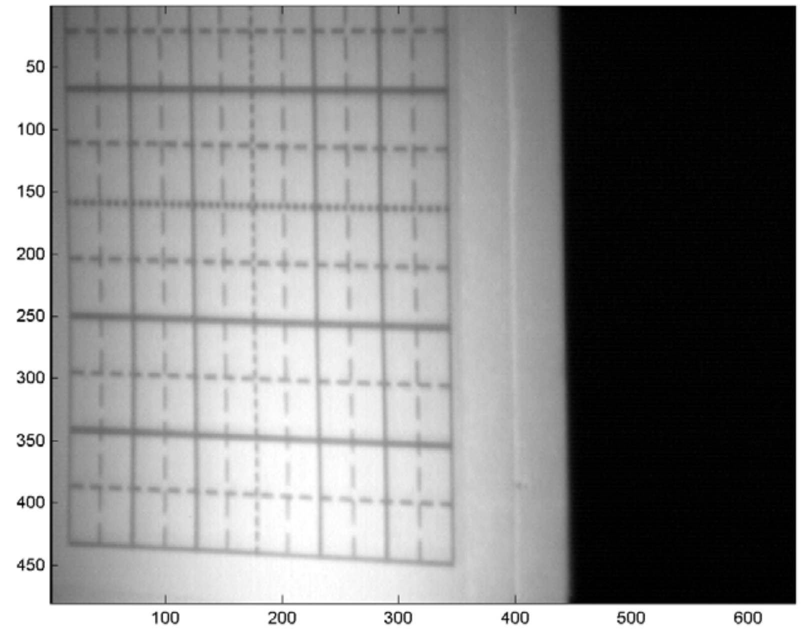
Calibration

- Changing foil changes position and scale
- Need in-situ position and scale calibration
- Cu, Ni and Au fiducial marks too dark – specular
- Back-lit holes appear to work
  - making holes an issue?
  - laser/mechanical/EDM?
  - best way to illuminate holes?
  - testing methods

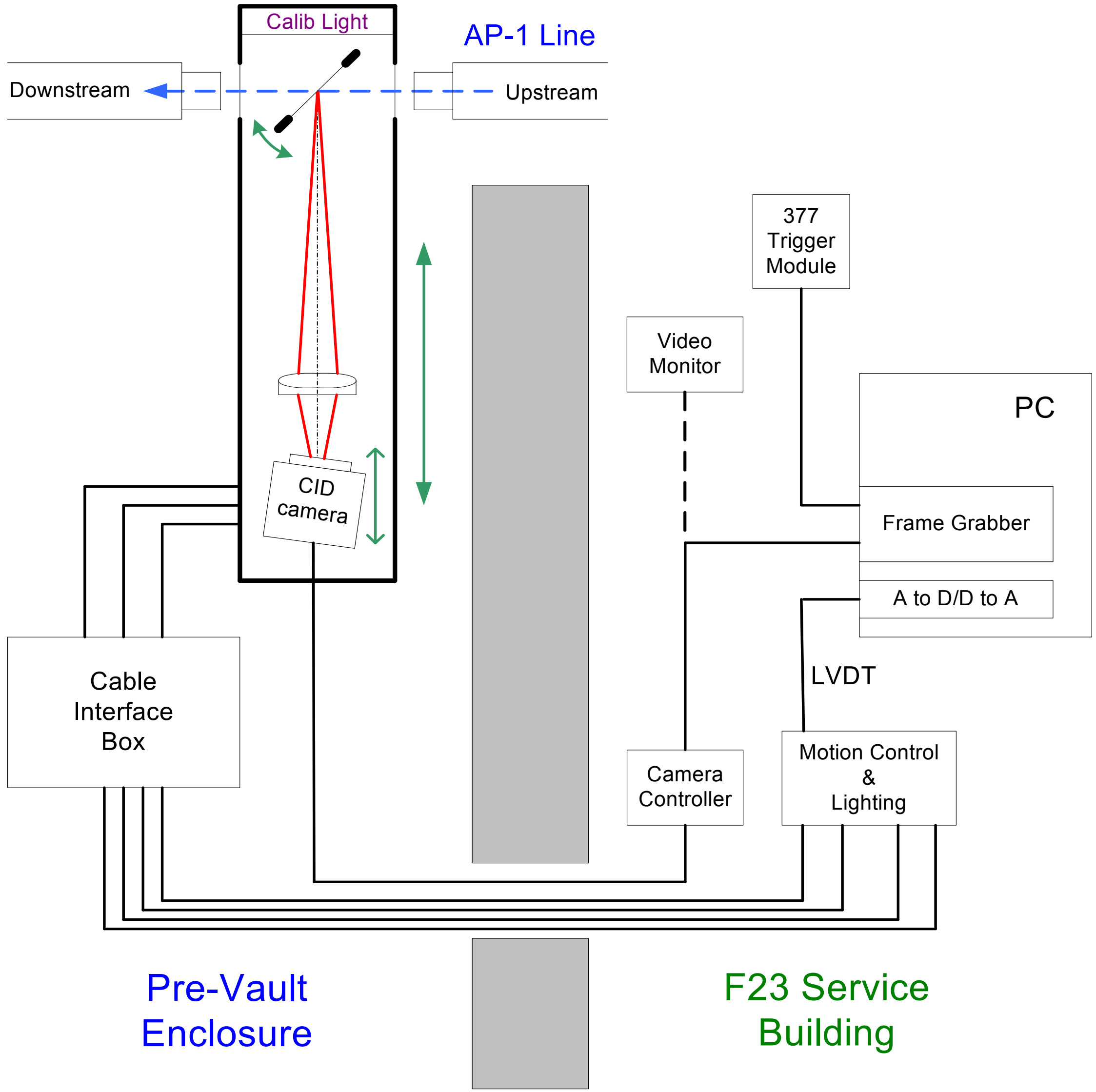


Aberrations and Distortion

- Use of single lens not well corrected for optical aberrations
- Distortion needs to be mapped and corrected
  - Distortion measured before placing in prevault
  - Need accurate distortion target

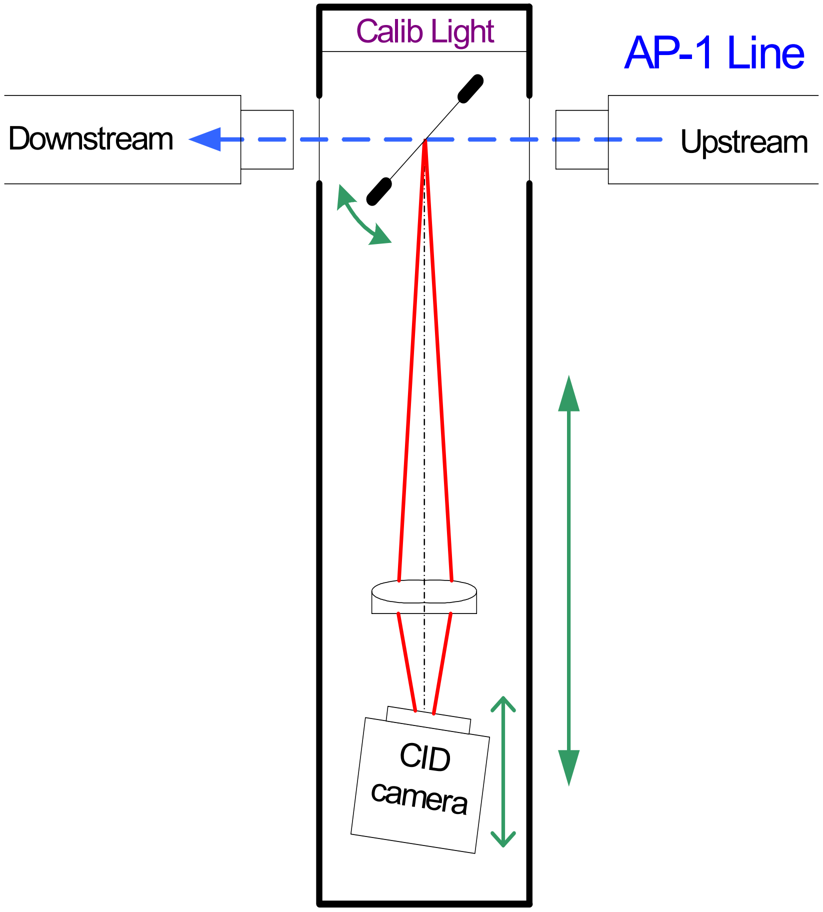


Prototype OTR Block Diagram



OTR Tube Mechanical Design

- Design by Carl Lindenmeyer
- Motion:
  - in/out of beam
  - $\theta - \phi$ tilt of foil (2 LVDTs)
  - camera focus (1 LVDT)
- Easy access to camera, lens and foil
  - tilt/no-tilt for camera (manual)
- Camera/lens position adjustable
- Neutral density filters optional
  - remote control
- Calibration light in design
  - radiation issues



DAQ System and Analysis

- Rack-mount PC with frame grabber
  - ADC to acquire LVDT positions
  - Labview image acquisition software (already purchased)
    - matched to frame grabber
- Rack-mount motion controller and illumination
  - pushbutton controls and LVDT displays
  - drivers for stepper motors
  - variable illumination intensity control
- Trigger – 377 module off TCLK event
  - sync camera to beam arrival

Personnel

- Instrumentation – Vic Scarpine, Warren Schappert, Gianni Tassatto
- Mechanical Design – Carl Lindenmeyer
- Pbar – Jim Morgan
- Foil mounting – Karen Kepart
- Foil fiducial marks – Eileen Hahn
- OTR Consultant – Alex Lumpkin (Argonne)

Apologies to anyone forgotten

Prevault OTR Costs

- Mechanical - tube (minus camera), cable interface, motion controller
  - $5000 for purchased parts
  - $5000 for outside machining
  - ~ 120 MDM machine hours (~$6000)
- CID camera, controller and cable - $2500
- PC, frame grabber, AD/DA - $3000
- (Optional: Rad-hard quartz lens - ~$8000)
- Misc - ~$1000

Total: $22,500 ($30000)

Status

- Optical image testing on bench proceeding
- Cables pulled in prevault
- Tube, cable interface and motion controller
  - rough design near complete
  - mechanical construction ~ 8 weeks from now?
- DAQ system and software
  - manual image acquisition working
  - perform image analysis offline
  - trigger interface in design

Schedule

	APRIL				MAY				JUNE				
	7th	14th	21st	28th	5th	12th	19th	26th	2nd	9th	16th	23rd	30th
Lighting Design	XXXXXXX	XXXXXXX											
Mechanical Design	XXXXXXX	XXXXXXX											
Mechanical Fab		XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX					
Mechanical Testing									XXXXXXX				
Image Calibration									XXXXXXX				
Mechanical Install										XXXXXXX			
F23 Layout		XXXXXXX											
F23 Install										XXXXXXX			
Image Testing	XXXXXXX	XXXXXXX	XXXXXXX										
Trigger Testing			XXXXXXX	XXXXXXX						XXXXXXX			
Labview Software Dev				XXXXXXX	XXXXXXX								
First Beam to OTRD										**X**			
Al Foil Testing											XXXXXXX		
Ti Foil Testing												XXXXXXX	
Quartz Lens Testing													XXXXXXX
	XXX = Dependent on prevault access												

Issues

Prevault Radiation Levels

- TLD badges exposed to ~4 weeks of stacking beam
- All badges overflowed on γ and neutrons
  - $\gamma > 1$ krads
  - neutron > 25 rads
- Closest badge had > 4 krads
  - location of lens and camera
- Prevault radiation levels unknown
- Work environment issues?
- Material activation and disposal?
- May force quartz lens solution

Long-term Radiation Issues

Foil darkening by beam?
Replace foils often?