Streak camera detector for slicing signal measurements

Aim:

- To reduce the requirements for optical scattering suppression at the first mirror in beamline 6.0 (and/or the amount of vertical dispersion in the accelerator)

Technique:

- By sweeping out the 80ps X-ray bunch signal with a streak camera with ~2ps temporal resolution, we can reduce the background contribution by ~40x (500μm slit, 50μm beam stretched out to 50μm at 6°).

- Compared to an MCP detector with ~20% efficiency, streak cameras typically have only a few % normal incidence efficiency. By operating the camera at grazing incidence we should be able to enhance the efficiency by a factor of ~10.
- Total signal to noise should therefore be increased by more than a factor of 40.

Schematic of the camera

CsI photo-Cathode. -10kV

Meander sweep plates

Magnetic lens

MCP fibre-coupled to a CCD

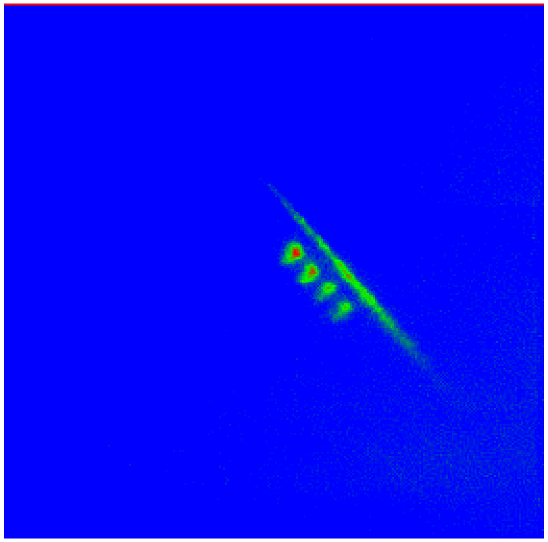
Recorded Streak image

Anode (0V) (~50µm slit)

Output data format

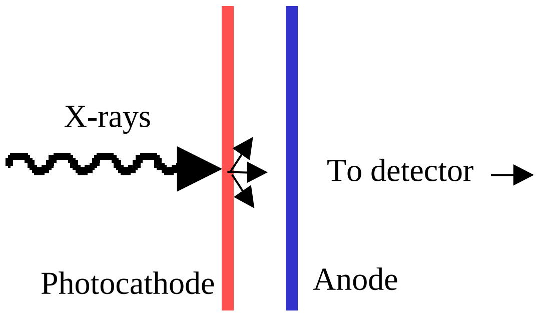
- The data recorded by a streak camera is a 2D image where the sweep dimension represents time, the other dimension represents space (along the entrance slit). Provided care is taken with filtering, the signal in the 2D data array is linear with the intensity of the incident radiation.

- ~60ps X-ray pulse superimposed on 4 UV pulses
- UV pulses integrated for several seconds at 1kHz
- 20ps increment between UV pulse records
- Resulting jitter is better than ~5ps.

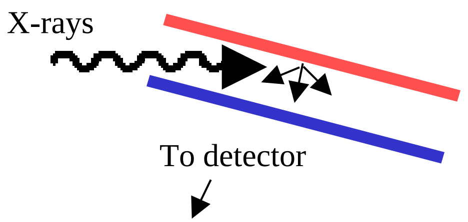


Reflection vs transmission cathode geometry

- The geometry of the camera has to be modified to admit photons to the front surface of the photocathode:
  - The X-ray signal projected onto the photocathode will be spread spatially
  - A temporal gradient will be imposed on the streak image due to the path difference introduced



Transmission Photocathode



Reflection photocathode

Secondary electron yield:
Angular dependence (Gaines)

The number of secondary electrons liberated per incident photon:

$Y_S \quad E_x \rho \, \mu(E_X) \, \lambda_S / (E_s \cos\varphi)$ (Henke *et al.*)

Where:

- E_x : X-ray energy
- ρ : Photocathode density
- $\mu(E_X)$: Mass absorption cross section
- λ_s : Secondary electron escape depth

  (~250Å for CsI)
- E_s : Mean secondary eletron energy
- φ : Angle between X-rays and

  cathode normal

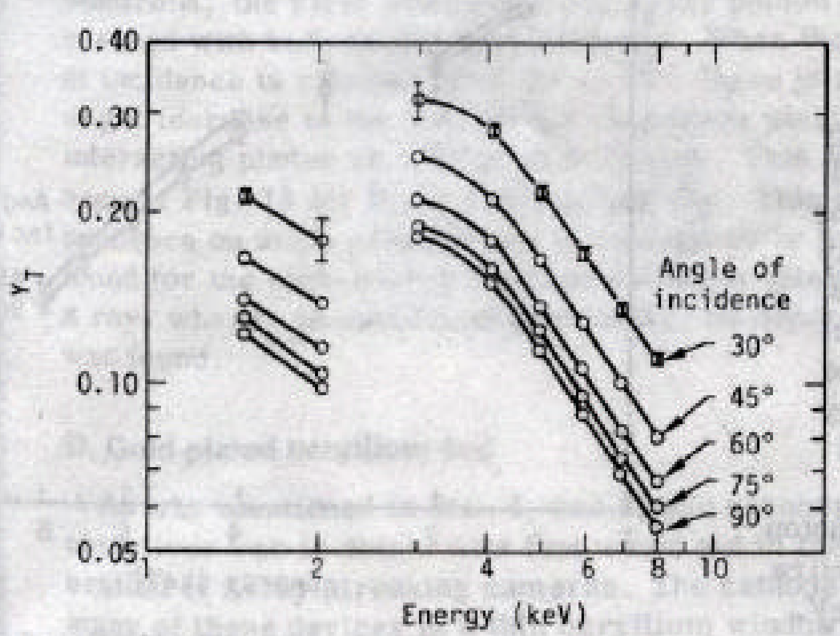


FIG. 6. Y_T vs energy for various angles of incidence (foil thickness, 0.194 mg/cm^2).

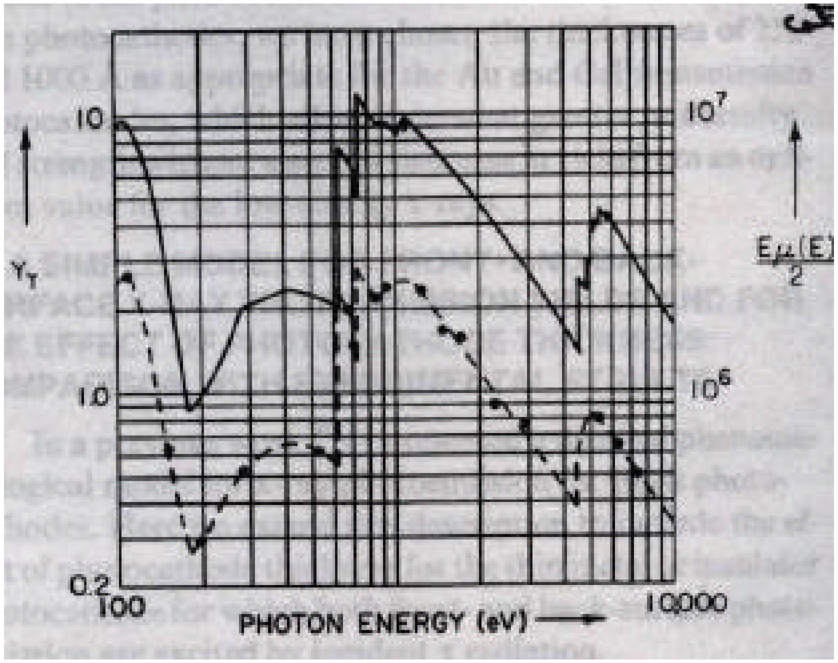
Gaines, J.L. *et al.* J.Appl.Phys **47**(9) 3923(1976)

Implications for streak cameras

- The secondary electron quantum yield for CsI is ~10x that for gold (Tx.)
- The quantum yield at the front surface is approximately 4x that at the back surface.
  - 1keV X-rays, normal incidence.
  - Optimised thickness for transmission cathode ($4\lambda_S$), $12\lambda_S$ for front surface yield
  - Low extraction fields (~24kV/m compared to 40MV/m in the camera)

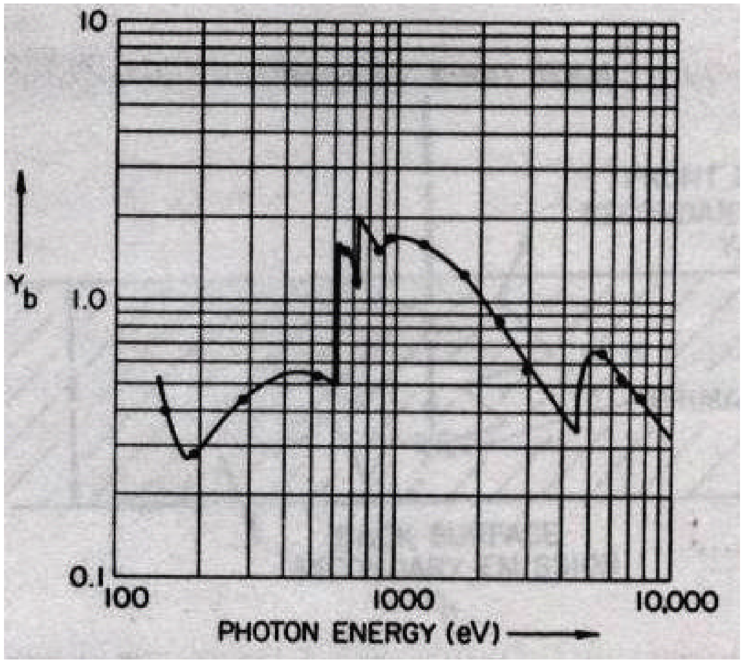
- The quantum yield should vary with the angle between the incident X-rays and the cathode normal as $1/\cos(\varphi)$ (assuming refraction is small) (photoexcitation vs escape)
  - This agrees with measurements by Gaines on Au for $0° < \varphi < 60°$.
  - At ~84° this should enhance the yield by ~10x compared to 0°.
  - Total enhancement compared to optimised transmission CsI cathode is greater than ~20x.

CsI Quantum Yield:
Front surface vs back surface (Henke)



Y_T: Front surface total quantum yield for 3000Å CsI

Eμ(E): X-ray absorption cross-section (for photoionisation)



Y_b: Back surface quantum yield for 1020Å CsI