The Development of an Improved Streak Tube for Fusion Diagnostics

J Howorth[(a)] J S Milnes[(a)*], Y Fisher[(b)], R Boni[(c)] & P A Jaanimagi[(c)]

The fusion diagnostic community require optical recording instruments with precise time resolution covering a dynamic range of many orders of magnitude. In 2012, LLE, Photek and Sydor Instruments embarked on the re-design of an improved Streak Tube for Fusion Diagnostics. As a baseline, we started with the Photek ST-Y streak tube which is a member of the RCA design dating back to 1957, because the tube body can accommodate a 35 mm long photocathode. Electron optical modelling was carried out by both Jaanimagi and Photek in a parallel exercise.

Our goal was to address some of the short-comings of this tube, the initial approach being to increase the field between the photocathode and extractor electrode. Many changes and modifications were made: the predicted time resolution was improved to 2 ps, the usable cathode length was increased to 32 mm under high extraction field operation and the off-axis spatial resolution was substantially improved compared to other tubes of this format.

Several tubes have been built and preliminary results obtained using a Sydor ROSS 5800 streak camera.

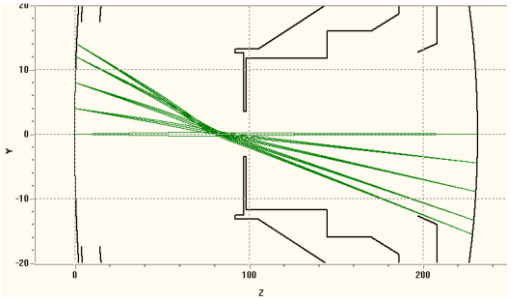
Photek ST-DS Streak Tube

Initial Modelling Stage

- We began by taking standard parts and modelling a streak tube with a 3.5 mm photocathode to slot gap using MASIM software:
  - Predicted spatial resolution is good in the centre (> 60 lp/mm) but falls away badly at a radius of more than 8 mm (~ 10 lp/mm)
  - The magnification was ~ 1.16, which restricts the useful photocathode length to ~ 19 mm
  - Predicted time resolution was fairly uniform at ~ 7 ps FWHM
- The following modifications were introduced:
  - Reduce photocathode – slot gap to 2 mm to improve time resolution & dynamic range
  - Reduce radius of the photocathode to flatten image plane and improve spatial resolution across the entire working area
  - Widen deflector plate gap from 1.8 mm to 4 mm to increase the throughput

Double Slot

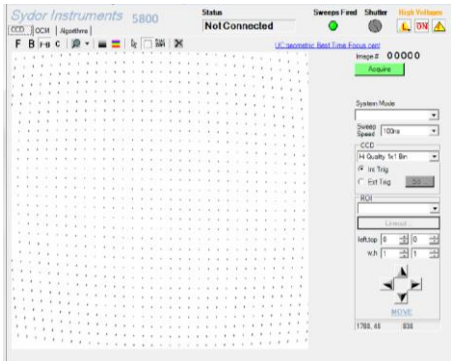
- The field lines near the slot are heavily distorted across their width, behaving like a cylindrical lens in conventional optics
- This could be compensated by placing a second slot immediately behind
- Adjustment of the second slot potential allows control of the cylindrical lens and magnification in the temporal axis
- In the first designs there was much promise but the crossover point tended to be about 20 mm in front of the cone aperture which restricted the useful length of the photocathode
- The cathode to cone dimension was reduced and the focus electrode was extended
- Working length was increased to 25mm as shown (see right)
- The relative voltages on the two slots and focusing electrode dictate the compromise between time resolution and working area / magnification
- A set of voltages that favours a good working area is gate-able

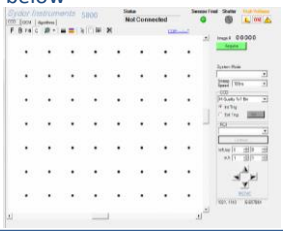


- This image is heavily compressed in the x-direction

Distortion

- The phosphor screen radius matches the image plane and is optimised for spatial resolution
- The predictable barrel distortion is shown in this pinhole image, taken in a slow sweep mode
- This distortion is corrected by Sydor's GeoCorrection software routine as shown below

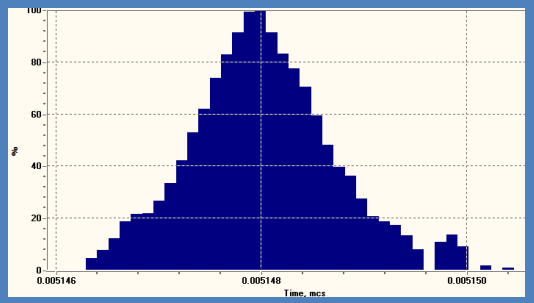




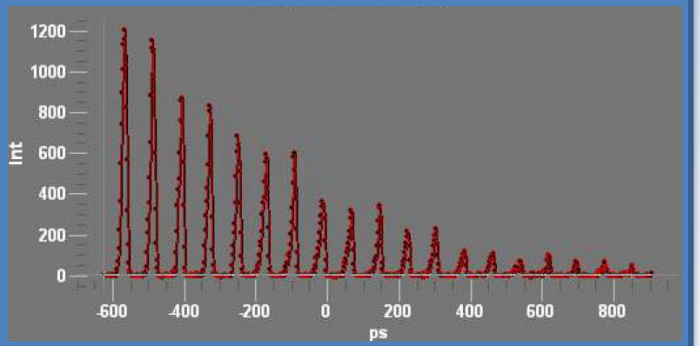
- This image is a 4X zoom of the upper part of the sweep. The spots are round, undistorted and in good focus all over the image

Time Resolution

- After the addition of the double slot the transit time was predicted to be 5.1 ns with a spread of just 1.3 ps FWHM in the centre (see below)
- The spread varies considerably over the surface, the response for the tube as a whole is predicted at ~ 6 ps FWHM



- Initial measurements in a Sydor ROSS 5800 camera (not optimised) and using an 80 ps etalon show < 13 ps FWHM (see below)



(a) Photek Ltd, St Leonards on Sea, East Sussex, UK.
(b) Sydor Instruments, Rochester, NY
(c) LLE, Rochester, NY
* Presenting Author

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