X-Chron 540 - a new picosecond x-ray streak camera

Roger Hadland. David Ecwley. Jo Honour.

Hadland Photonics Ltd. U.K.

Introduction

A new soft x-ray and V-UV sensitive streak camera has been developed to meet the fusion research requirements of Los Alamos and Livermore National Laboratories.

The main performance parameters called for were-
Large number of spatial channels
Longest practical cathode
Undistorted streak image

These parameters have been optimised in the Imacon 540, which is based on expanded Photochron II optics. The image tube is demountable and incorporates its own vacuum pumping system allowing it to be run independently of the event chamber.

Cathodes can be inspected under vacuum and rapidly changed if damaged.

A number of streak circuits are available, suitable for picosecond to microsecond events, as well as Synchroscan and fast framing modules.

Early x-ray streak tubes were made by modifying visible streak tubes with a demountable front flange and gold-on-beryllium cathodes. Ref. 1.

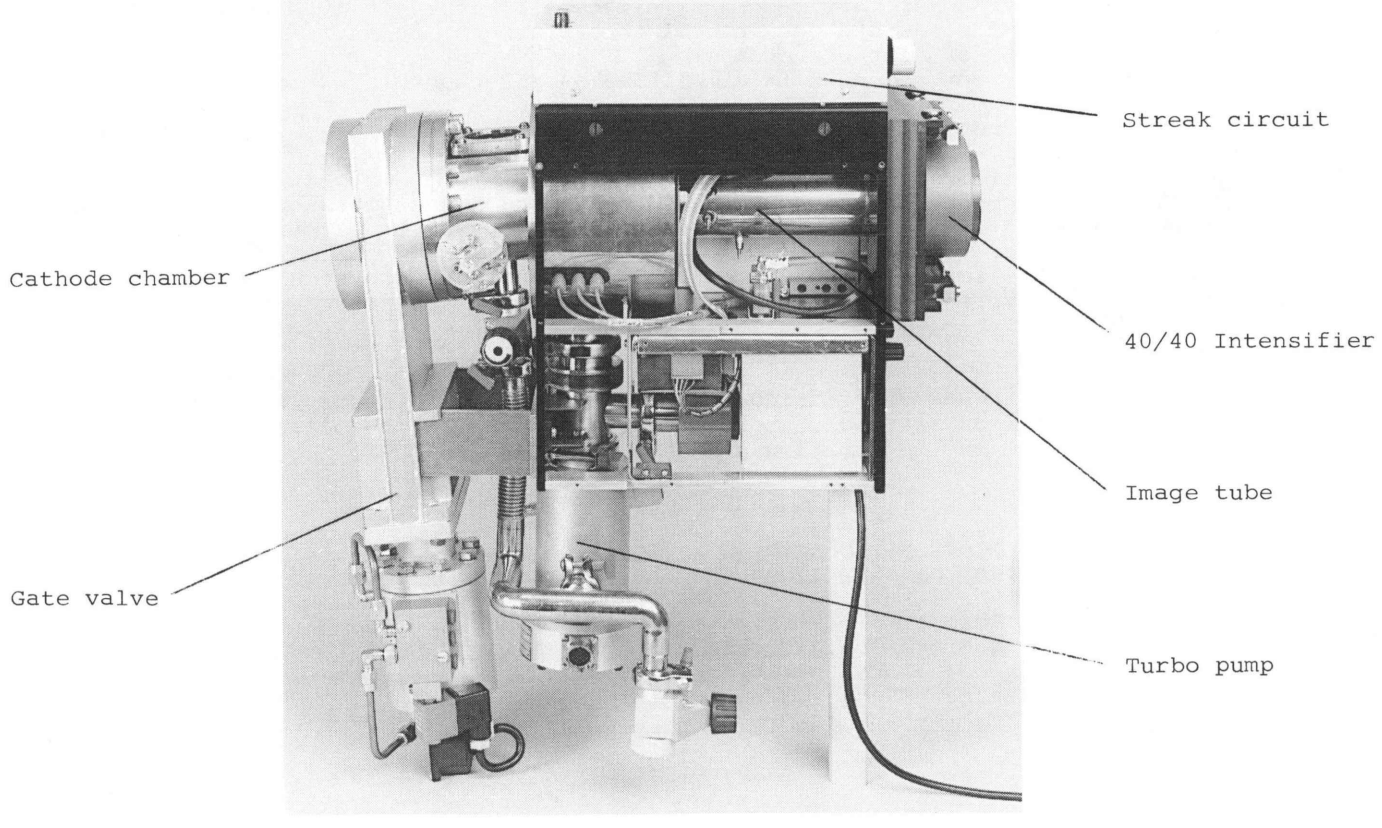

Fig. 1.

The tube was evacuated via the event chamber, which frequently operated at too poor a vacuum to give reliable operation. This problem became more severe when Photochron II geometry was introduced as the high electric field strength between cathode and grid required a minimum vacuum of 10^{-5} mbar. Some sealed tubes have been made but they had poor sensitivity below 1Kev as the cathode window had to be thick enough to withstand an atmosphere. Ref. 2.

The first x-ray streak camera with integral pumping was made at LLL. A number of these cameras have been made, based on the R.C.A. tube and continuously pumped with an 8 litre/s ion pump. A novel feature of this camera was the cathode manipulator section, which allowed the photocathode to be inspected and changed through an access port. This required the tube to be vented to atmosphere, the complete cycle taking some hours.

However, the R.C.A. tube is not ideal for conversion to x-ray wavelengths as the extraction field at the cathode is low, the photocathode should ideally be curved, and the grid wires introduce geometric distortion.

The X-chron 540 was developed to a specification laid down by the Los Alamos National Laboratory to incorporate the best features of previous cameras and improve on the number of spatial data channels. System flexibility, ease of operation and rapid cathode changes with precise relocation were essential pre requisites.

The main components of the X-chron 540 are shown in Fig. 1. In addition there are rack mounted turbo pump and vacuum gauge controls and a 1.5 cu M/hour backing pump.

Imaging Section

This comprises the cathode chamber, interface casting and image tube. The tube is constructed of stainless steel and ceramic, with ceramic insulated feed throughs for deflector plates. Fig. 2. It is totally demountable, the focus cone and anode being removable from the front, the screen cap from the back.

The imaging section is based on Photochron II geometry, with 1KV between cathode and grid, separated by 0.5 mm.

The standard Photochron II has a maximum cathode size of 10 mm, but in this case it has been extended to 20 mm along the space axis. The deflector section has been shortened to reduce the usual 1:2 cathode: screen magnification to 1:1.75. The screen is a 40 mm dia. P.20 phosphor of medium persistance, which gives optimum spectral matching into the intensifier. Alternative screen caps with P47 and P11 rapid decay phosphors are available. The cap can be shortened and the tube refocussed to reduce magnification down to 1:1.2, which is more suitable for direct electron stimulation of CCD and MOS devices placed inside the tube.

The image tube is attached to the interface casting by screws and an O-ring seal. A register plate screws in the front of the casting and precisely locates cathode and grid.

The manipulator chamber is attached to the front of the casting.

The manipulator arm function is to present the cathode to the register plate for operation; withdraw it for evacuation; position it for inspection and project if through the top window for changing. All but the last function can be carried out under vacuum, so a cathode can be inspected just prior to use.

The grid is inserted through a small port in the top of the casting. If either cathode or grid are damaged, they can be changed in 5 minutes once the system is vented. Separation is maintained at 500 ± 25 microns and replacement cathode slits relocate also within $\pm$ 25 microns, so image realignment is unnecessary.

Working cathodes are 0.1 x 20 mm long and use 30 nm gold evaporated on 50 mm Parylene substrate. For setting up purposes, a UV light source is used with a gold test chart pattern on Spectrosil substrate.

Vacuum System

The tube is evacuated by a 25 litre/s turbo pump attached to a large port set into the interface casting. With a 1.5cu M/s backing pump the tube and cathode chamber can be pumped down to operating levels in 20 minutes and to an ultimate vacuum of around 10^{-6} mbar. By locating the pumping port close to the cathode, the best vacuum is achieved in this region and corona problems are eliminated. Vacuum is measured with a built-in Penning gauge.

Before pumping, the cathode is withdrawn from its operating position, as it forms a seal between cathode chamber and tube. Both chamber and tube are rough pumped through separate routes, to avoid drawing air through the mesh grid and possibly trapping dust particles.

After 1 or 2 minutes the chamber valve is closed and both chamber and tube pumped through the interface casting.

Prior to operation, the cathode is moved to the operate position thus isolating chamber and tube, and the gate valve is opened. Event chamber vacuum as poor as 10^{-3}mbar can be tolerated with momentary over pressures during the event pulse, without affecting camera operation.

Electronics

The streak circuit is derived from the proven Imacon 500 design and provides writing speeds from 20 ps/mm to 5 ns/mm. This gives a time window of 800 ps to 200 ns over the 40 mm diameter. Trigger jitter is normally less than ± 25 ps and delay to write is 8 ns at the maximum speed.

Versions of other Imacon 500 drive circuits are available, giving slower streaks and Synchroscan operation in the 62 to 250 MHz range.

Multi framing operation is available provided the image tube is fitted with 2 pairs of deflector plates operating in the same axis. Framing speeds of 75, 150, 300 and 600 million frame/s are available. The method of operation was first described in conjunction with an Imacon 600 and produces a single row of 4 to 10 images. Ref. 3.

All power supplies and trigger circuits are incorporated in the camera body, with the exception of the turbo pump and Penning gauge controls. The camera is designed to use at ITT 40/40 proximity type channel plate intensifier and all power supplies and Synchroscan circuits are built in.

Performance

For all operations requiring sub nanosecond resolution, the channel plate intensifier is necessary and was used for the results shown below. Static resolution referred to the cathode is 20 lp/mm over at least 50% of the format, decreasing to 15 lp/mm at the edges. This gives a minimum of 375 resolvable channels along the 20mm slit length.

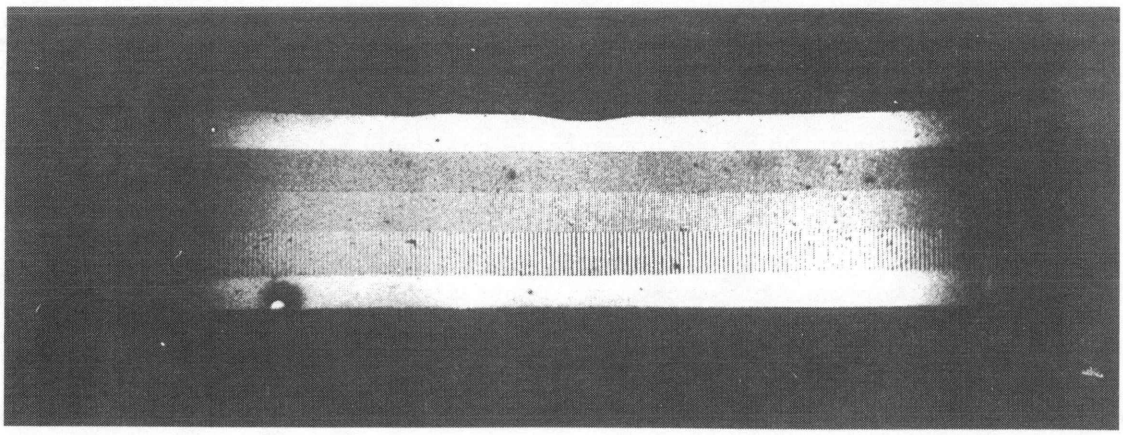

Fig. 2.

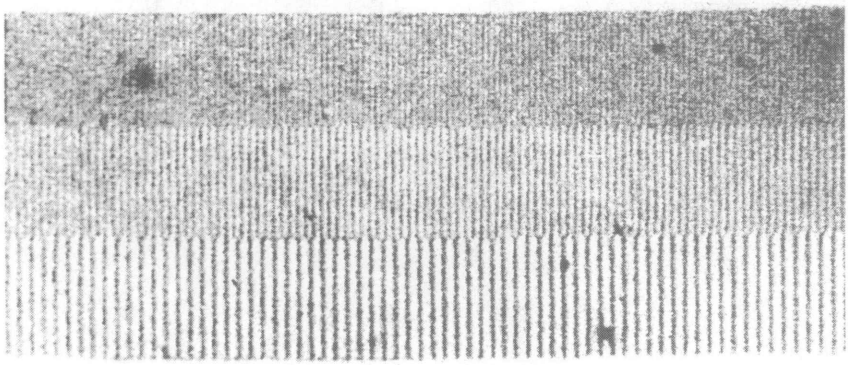

Fig. 3.

The expanded cathode of the Photochron II is flat, which simplifies x-ray imaging, yet retains high geometric precision in the image tube. Slit curvature and distortion along the time axis is almost undetectable, although transit time differences cause image curvature at maximum scan speed. Limiting dynamic spatial resolution in excess of 20 lp/mm as demonstrated on earlier Photochron II x-ray camera tests at LANL.

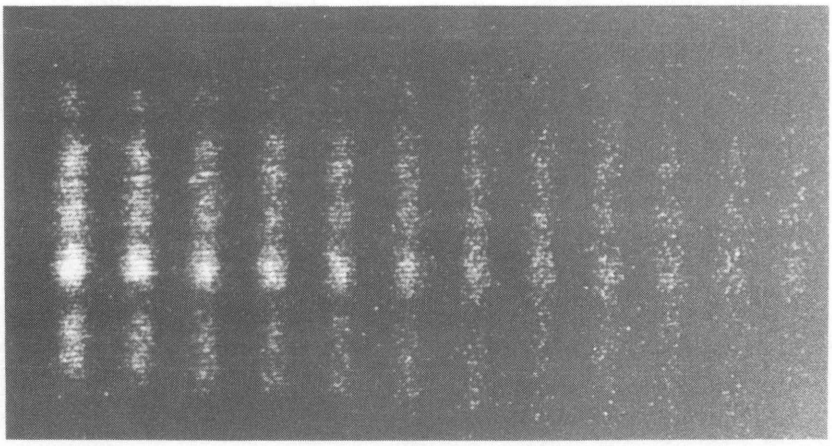

Fig. 4.

Fig. 4. shows a preliminary dynamic result from the X-chron 540, using 30 ps frequency quadrupled 1.06 micron pulses at 100 ps intervals recorded with a gold/parylene cathode. The spatial resolution is 13 lp/mm and streak linearity is better than + 4% across the 40mm screen.

The contributions of Gary Stradling of LANL who has advised on many aspects of the design, and Hector Medecki of LLNL who devised the original cathode manipulator, are greatly appreciated.

References

1. Bird, P.R. Bradley, D.J. Roddic. A.G. Sibbett. W. Picosecond Chronography at x-ray wavelengths 11th International High Speed Photography Congress. University of London 1974. Pages 118 - 123.
2. Attwood, D.T. Coleman, L.W. Houghton, J.W. Time Resolved x-ray emission Annual Laser Programme. Annual report 1975 at the Lawrence Livermore Laboratories. Page 418.
3. Huston, A.E. A 300 million frames per second image tube camera Proceedings of the 9th International Congress of High Speed Photography 1970 Pages 183 - 185