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A Laser Diode as a Light Source for Calibrating the Time Base of a Streak Camera

Neutron Emission Profile Measurements during the First Tritium Experiments at JET

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ABSTRACT

The DC operation of some laser diodes produces high frequency amplitude modulation of the laser output in the GHz frequency range. This phenomena provides a simple and inexpensive method for checking the sweep linearity of a fast gated streak camera.

We have used a gated Thomson-CSF streak camera (model TSN506) as an alternative detection system to MCP photomultipliers in the LIDAR-Thomson scattering diagnostic on the JET tokamak [1, 2]. The faster response time of the streak camera has allowed us to obtain higher spatial resolution electron temperature and density measurements in the plasma [3]. We now plan to use the same detector system in a new LIDAR diagnostic for the divertor region [4]. In the LIDAR Thomson scattering technique, a non-linearity in the sweep speed could result in a misinterpretation of the shape of the electron density and temperature profiles. A calibration of the sweep linearity is therefore essential.

In a paper presented recently by Tou, the author used a sequenced multi-spark switch to calibrate streak cameras operating at ns streak speeds [5]. Tatum, Jennings and MacFarlane describe a 100 ps 10^8 Hz pulser to drive laser diodes [6]. In the course of assessing the performance parameters of the streak camera we found that laser diodes operated in CW mode, i.e. connected to a battery power supply, show a strong high frequency modulation of their output. This modulation was achieved without additional high frequency circuitry. We used this phenomenon to test the linearity of the streak camera sweep and this work is reported here. The rapid modulation of the laser output is in the GHz range. The modulation depth can be controlled to some degree via the driving current, but duty cycle and frequency response appear to be fixed for every laser diode. The individual performance parameters of the diodes do vary. The duty cycle of the high frequency response appears to decrease for diodes with shorter emission wavelengths. For our calibration we used a Sharp Laser diode Model LT022MDO emitting at 780 nm, which showed a duty cycle of about one to four (100 ps pulse width and a 380 ps gain switch). These measured parameters were not inconsistent with the manufacturer's specification for this type of laser diode, since the diode is clearly a high frequency device with a quoted modulation bandwidth of greater than 6 GHz. Several other diodes of the same type were also tested and all had pulse lengths from 100 to 150 ps and gain switches from 370 to 550 ps. We have found that diodes from other manufacturers (e.g. Toshiba, Sony) displayed similar features, but with different time constants and temporal emission patterns.

The JET streak camera has nominal streak rates of 60, 90, 120 and 150 ps/mm. For the measurement the laser diode, connected to a small 9V battery and a variable series resistor, was placed in front of the camera using a lens to focus the output directly onto a small spot on the photo-cathode. The lens position was optimized to give the smallest possible focus guaranteeing that the temporal resolution was not compromised by the finite spot size. Trigger timing was not a problem in our set-up because the camera was always operated in a gated mode, avoiding the need for synchronization of the output of the light source with the sweep interval of the streak camera. The streaked image was intensified using an MCP intensifier and then recorded by a CCD camera. The recorded image was displayed on a PC using a customized version of the Facet Norma display program (Thomson CSF). The intensifier voltage was adjusted to optimise the signal level.

The sweep rate and linearity had previously been tested both by the manufacturer and at JET using 50 or 300 ps laser pulses as the light sources [7]. Multiple pulses were produced using two partially reflecting mirrors in the laser beam path. In this way two or more laser pulse reflections at accurately known intervals could be recorded in one streak picture. Using the laser diode technique more pulses could be recorded (6 pulses for 60 ps/mm up to 12 for 150 ps/mm) (Fig 1a) and it was clear that the streak speed was not constant across the screen for slower streak speeds (Fig 1b). Measurements with streak speeds of 120 ps/mm and 150 ps/mm indicated that the speed was about 25% faster near the end of the streak screen. Tests of the laser diode output made with a vacuum photodiode and oscilloscope showed no variation of its output frequency with time (when it was operated at constant temperature and current). Thus we conclude that the variation in pulse separation is due to the sweep variation of the streak camera. The stray magnetic field in the JET environment accounted for the discrepancy between the laser pulse and laser diode measurement of the sweep linearity. Shielding the camera removed the effect.

The high frequency amplitude modulation shown by most laser diodes when operated in CW mode supplies a convenient, cheap high frequency light source for testing the sweep linearity of streak cameras. With diode performance parameters varying over the GHz range it should be possible to select an adequate modulation frequency to test nanosecond as well as subnanosecond streak cameras. In addition we have found that laser diodes are useful light sources for calibrating sweep speed and quantum efficiency of streak cameras.

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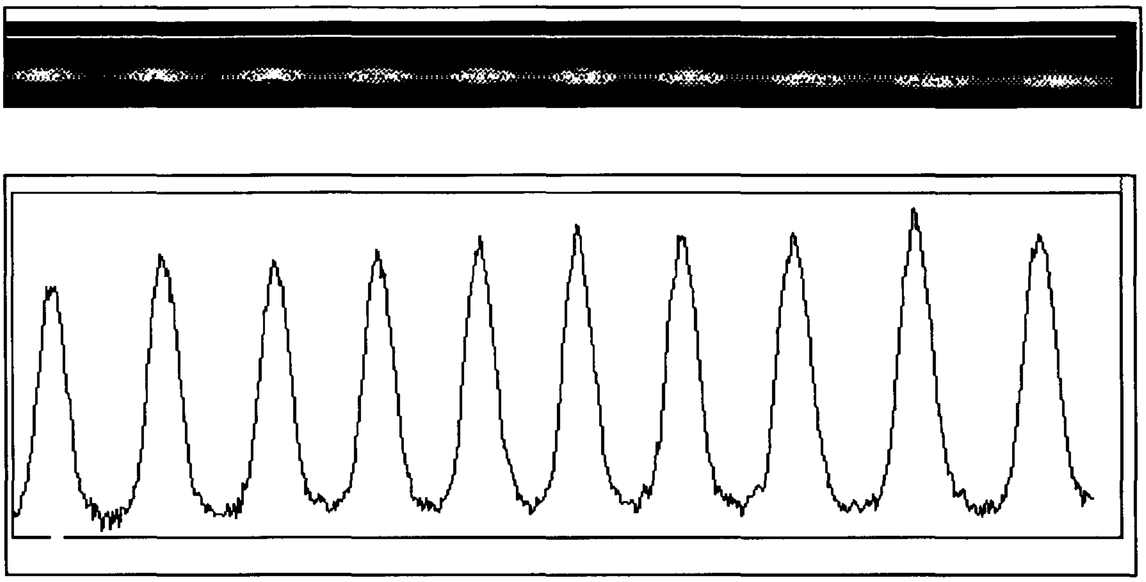

Fig 1a: Raw streak camera data (upper) and intensity integrated in vertical direction (lower). Streak speed 120 ps/mm.

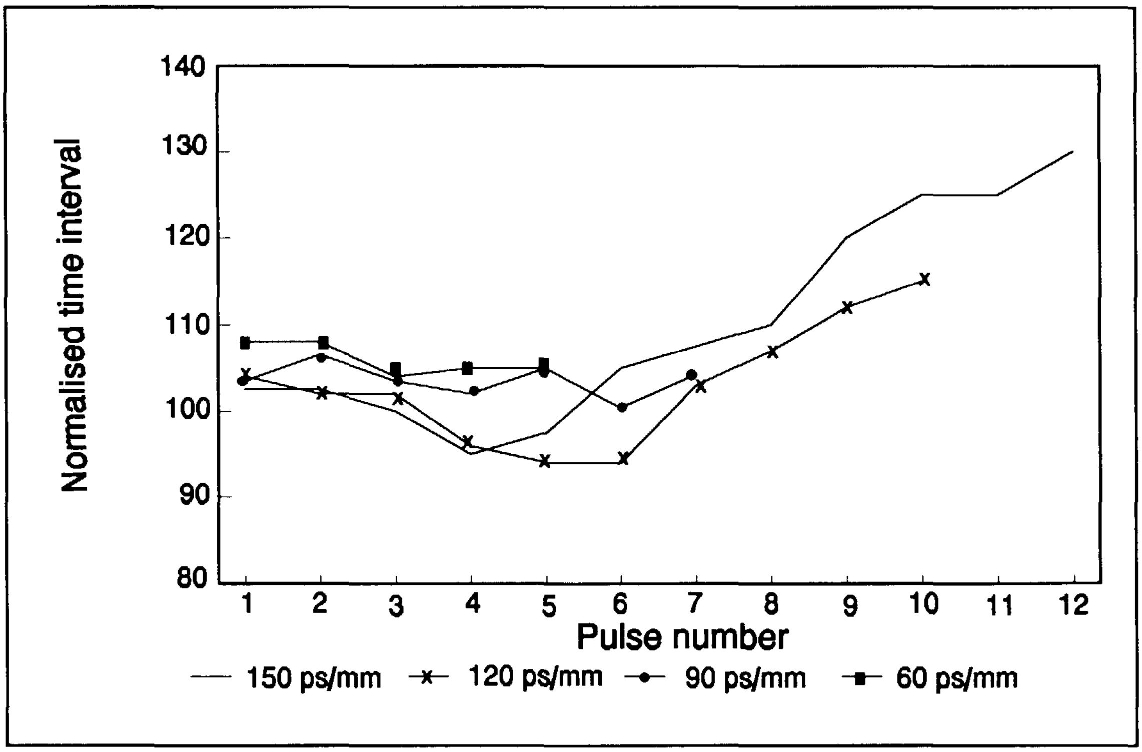

Fig 1b: Sweep linearity measurement.