Stability of high repetition rate plasma focus neutron source

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Abstract

The NX2 plasma focus has been operated in repetitive mode to investigate the effect of repetition rate on neutron emission stability of the device. For novel applications, requiring short pulses of neutrons, the stability of the shot to shot neutron yield may also be important. The stability of neutron emission for a range of repetitive rates from 1/5 to 3 Hz has been investigated. The shot to shot yield was estimated using a beryllium activation counter which detects neutrons with energy >1 MeV. The shot to shot variation for 50 focus shots were analyzed for a given repetition rate. Shot to shot variation in neutron yield is high with typical standard deviation approximately equal to average yield which is similar to the one found in single shot foci. It was, however, found that there was no significant change in average yield over 50 shots without gas change.

I. INTRODUCTION

Currently available practical neutron sources, based on radioactive material, give neutrons continuously. Neutron sources based on accelerator tubes can be pulsed. Short time scales of the order of 1μs can be achieved with reduction in average neutron production rate. The dense plasma focus (DPF) is a well known source of 2.5 MeV fusion neutrons. The compact size and short pulse nature of DPF has many potential applications [1], [2] as the emitted neutrons have very small energy range and are emitted in a short time. Thus the “brilliance” which we may define as total neutron energy per unit time per unit area of source size per unit solid angle of emission per energy bandwidth of the DPF neutron source is extremely high for NX2 in single shot mode this is of the order of 10^{20} s^{-1} sr^{-1} m^{-2} [spectral brightness or brilliance s^{-1} mm^{-2} $mrad^{-2}$ $bandwidth^{-1}$]. We report neutron yield measurements from a deuterium filled NX2 device for various repetition rates. The shot to shot variation for more than 50 focus shots were analyzed as this may be important for applications which require the pulsed neutron source to be stable over large number of shots.

II. EXPERIMENT

The NX2 dense plasma focus was used for these experiments. Details of the NX2 DPF device can be found in paper by Koh et al [3]. A voltage of 12.5 kV was used for various repetition rate experiments. The device can operate at charging voltage up to a maximum of 15 kV giving capacitor bank energy of 3.2 kJ and a short circuit current of 480 kA. A new detector was constructed for this experiment based on Beryllium sheet activation described by S. Mahmood et al [4]. Data from the detector was analyzed with proper consideration of counts from previous shots. Using this detector and analysis method, as described in Ref [4], neutron yield measurements up to a maximum repetition rate of 3 Hz can be measured. Data was taken at repetition rates from 1/5 Hz to 3 Hz and in the pressure range of 14mbar to 18mbar. This pressure range had been established to be good for neutron production from NX2 DPF operated in single shot mode as reported in Ref [3].

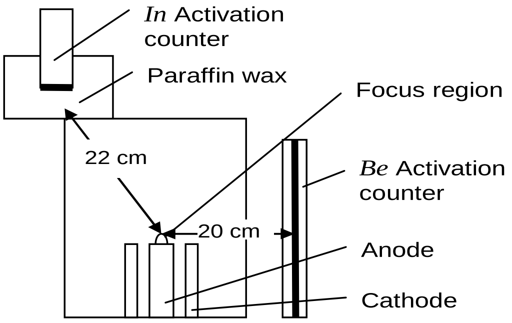

Figure 1: Schematic showing the positions of the Be and In detectors.

Figure 1 shows the setup for the neutron measurements. The pre-calibrated Indium activation detector was used to calibrate the new *Be* activation detectors in single shot mode (shots taken at 5 minute intervals).

II. RESULTS & CONCLUSION

Figure 2 shows corrected [4] repetitive *Be* counter data for 3 Hz shots with 12.5 kV charging voltage at 14, 16 and 18 mbar of Deuterium. It can be seen that shot to shot variation in neutron yield is different at different operating pressures for 3 Hz operation. The standard deviations for 14, 16 and 18 mbar operation at 3 Hz, as shown in Figure 3, are 50, 82 and 33% respectively. At 3 Hz repetition rate, the neutron yield at filling gas

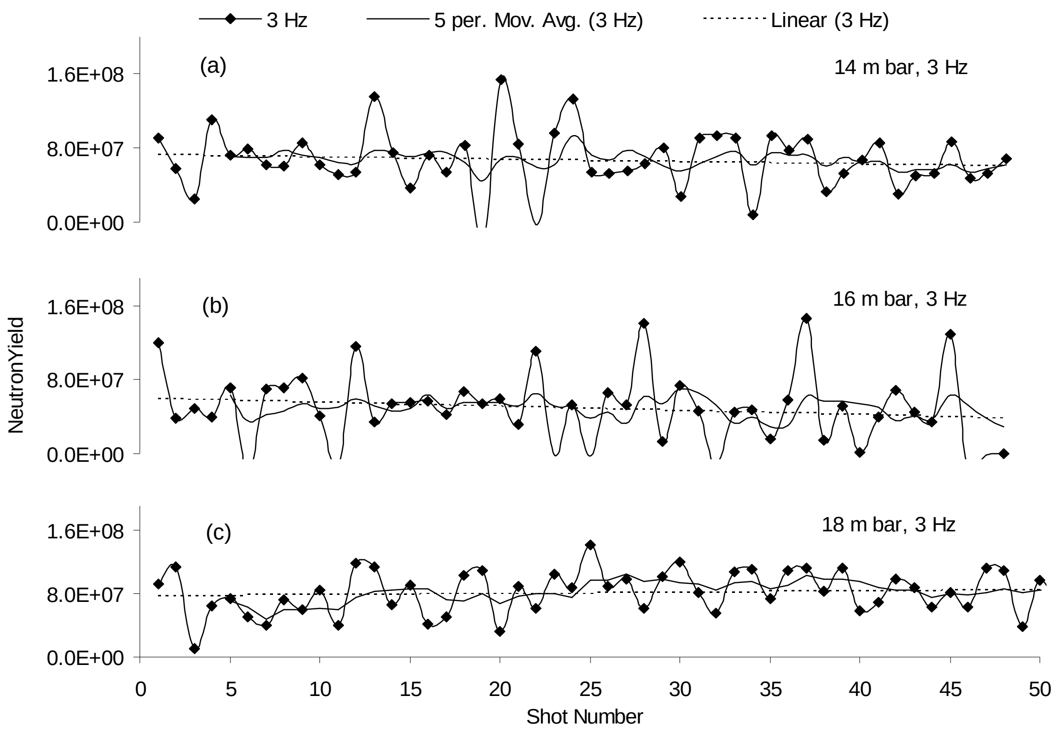

Figure 2: Corrected repetitive Be counter data for 3 Hz shots with 12.5 kV charging voltage (2.2 kJ) at a) 14, b)16 and c)18 mbar of Deuterium.

pressure of 18mbar seems more reproducible with relatively small variations in comparison with those at 14mbar and 16mbar where a number of shots are having practically zero yields and a number of shots have yields about twice the average.

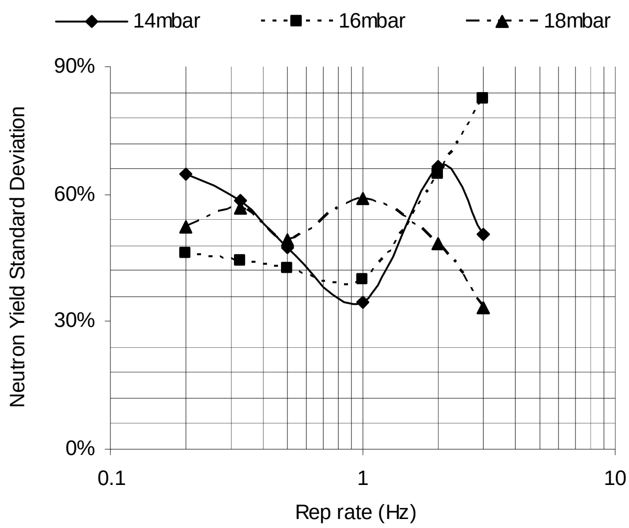

Figure 3: Variation in standard deviation of neutron yield at different rep rates.

Neutron yields were obtained for 1/5 Hz – 3 Hz. Neutron yields were of the order of 10^7 per shot. The standard deviation in neutron yield at different repetition rates for 14, 16 and 18 mbar DPF operations are shown in Figure 3. It can be seen that though there is no specific trend in the variation in neutron yield (randomly varying from 30% - 80%) but a proper choice of filling gas pressure and repetition rate may provide a relatively stable neutron yield from DPF device.

One of the main mechanisms for neutron production is beam target interaction. The deuterons from plasma focus have a wide spectrum with energy typically of the order of 100 keV [5]. The deuteron beam is generated by the plasma during the focus event when the plasma is on the verge of breaking up due to instabilities. The spectrum of the beam changes from shot to shot. This means that the yield will naturally have a large variance as the mechanism for neutron production is associated with the onset of instabilities and a small change in the deuteron energy spectrum will cause a big change in the reaction rates due to the cross section. Comparing the reaction rates of DT and DD (assuming that the spectrum follows a Maxwellian distribution for a given "temperature"), the rate of rise of reaction rate with respect to temperature for DT is comparatively lower than that for DD for temperature > 10 keV. Thus if DT were used instead of DD, it can be expected that the yield variation will be reduced as the reaction cross section varies less significantly at the particle energies typical of the plasma focus.

We have demonstrated low yield variation may be obtained using the NX2 plasma focus for certain gas fill pressure and repetition rate. It is expected that with a DT gas fill, it is possible to achieve 10^{11} neutrons per second with lower shot to shot variation due to the higher cross section of DT reaction at low energies and smaller rate of change of cross section with energy.

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