Source correlation factor measurement using D-T neutron generator

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Introduction

Accelerator Driven Subcritical (ADS) systems are being studied worldwide for their potential of burning minor actinides and reducing long term radiotoxicity. Various zero power subcritical systems (KUCA, MUSE, YALINA and BRAHMMA) have been developed to study the physics aspect of ADS using D-D or D-T fusion based neutron source. One of the important physics issue in ADS is to maintain the subcriticality throughout its operation by measuring the reactivity.

During 1960, on the basis of neutron correlation technique, noise methods such as variance to mean ratio (*v/m*) or Feynman-alpha and Auto Co-variance (*ACV*) were developed to measure the reactor kinetic parameters and reactivity [1]. Later, noise methods resumed interest with the proposal of ADS by Carlo Rubbia [2]. Theoretical and experimental work has advanced in continuous and pulsed mode using synchronous and asynchronous detection techniques [3,4]. These works have been carried out considering the external neutron source as Poisson character. But, this assumption is inappropriate for an accelerator based neutron source [5] and this can be explained with a simple example. Let us consider a D-T neutron source having yield 10^{10}n/s. Under the consideration of Poisson distribution, the variance will be its mean (M), the standard deviation (SD) will be 10^5n/s and the fluctuation (SD/M) considering Poisson distribution must be 0.001%. But, it is practically impossible to achieve such stability because of inherent fluctuation in beam current and accelerating voltage. Therefore, it is interesting to study the source characteristic which is relevant for noise studies in ADS system.

Methodology

The experimental setup consists of a D-T neutron generator, ^{3}He detector with electronics and time stamp data acquisition system. The neutron counts were registered with the incident time for duration (τ). The time stamp data has been analysed using *v/m* and *ACV* methods. For *v/m*, entire dataset has been divided into equal time segments (say T). The number of counts in each segment (*Z(T)*) was used to calculate the variance to mean ratio using eqn.1.

$$\frac{v(T)}{m(T)} = \frac{\langle Z(T)^2 \rangle - \langle Z(T) \rangle^2}{\langle Z(T) \rangle} = \frac{\frac{1}{N}\sum_{i=1}^{N} Z_i^2(T) - \left(\frac{1}{N}\sum_{i=1}^{N} Z_i(T)\right)^2}{\frac{1}{N}\sum_{i=1}^{N} Z_i(T)} \quad (1)$$

The *ACV* of the neutron counts is given by:

$$ACV(T) = \frac{1}{M}\sum_{i=1}^{M}(N(i\Delta t) - \bar{N})(N(i\Delta t + T) - \bar{N}) \quad (2)$$

where $\bar{N}$ is the DC part of the counts for time segment Δt.

Results and discussion

During source characterization, a ^{3}He detector (active length: 10cm and diameter: 2.54cm) has been placed at a distance of 10cm from the beam target. The detector was encapsulated by a Perspex cylinder followed by 2mm cadmium sheet. The Perspex was used to thermalize the fast neutrons and the cadmium to stop the scattered thermal neutrons from surroundings entering the detector.

The neutron generator was used with pulse repetition frequency of 10kHz having 10% duty cycle. The time stamp data have been divided into time segments of one second to study the source fluctuation. In Fig.1, the normalise counts per second (CPS) can be seen. The source fluctuation (Std/Mean) as shown in inset of Fig.1 is 2.0%. Data have been analysed using *v/m* method and the *v/m-1* is shown in Fig.2. In case of, Poisson source characteristics the *v/m-1* should be zero, whereas the measured v/m-1 is close to 0.1. Therefore, the neutron source having fluctuation of 2% and non-zero *v/m-1* cannot be assumed as Poisson character.

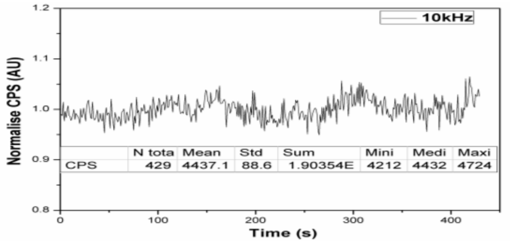

Fig. 1 Normalise CPS at 10kHz

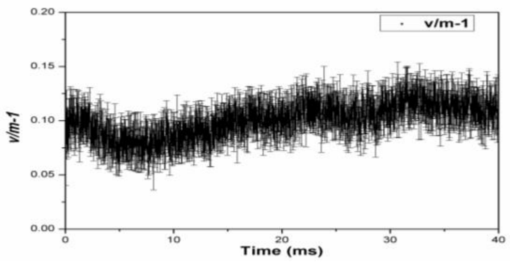

Fig. 2 *v/m-1* plot at 10kHz

In the next step, data have been analyzed using *ACV* method and the measured *ACV* has been shown in Fig.3. The *ACV* has periodicity corresponding to the source frequency and has exponential decay following the neutron pulse. Therefore, the source correlation factor and correlation time can be estimate from the exponential decay of the measured *ACV* and the values are 50.44±10.76ms^{-1} and 19.8±4.2μs respectively.

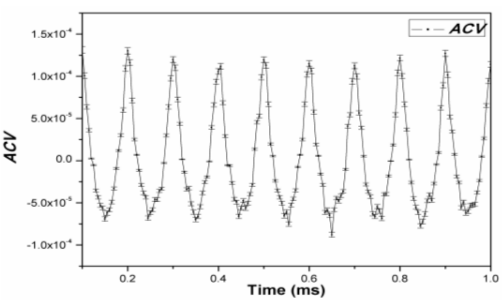

Fig. 3 *ACV* plot at 10kHz

The error in the measured correction factor is high. This can be attributed to the decay of *ACV* in high frequency, which is sharp and the number of data points is also less as shown in Fig.4. The measured source correlation factor is very high and the D-T neutrons have very short term correlation.

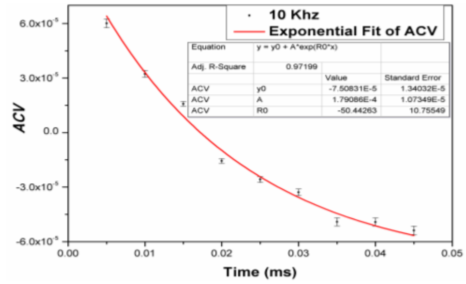

Fig. 4 *ACV* plot for source correlation factor measurement

Conclusion

An investigation of the source correlation factor has been carried out using D-T neutron generator and results have been presented for accelerator frequency 10kHz. The source correlation factor which appears due to inherent source fluctuation is very large. This new approach has been implemented to understand the source characteristics for noise studies in accelerator driven subcritical system.

Reference

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