Processing of the Signals From Plasma Focus Discharge

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Abstract. Recent experiments of D-D reactions at the PF-1000 device in IPPLM Warsaw made possible to determine more exactly the time and energy distribution of produced neutrons due to ten scintillation detectors placed at distances between 7 and 85 m from the neutron source in both axial directions. In this article the de-noising of neutron signal via wavelet transformation is described. The signals were filtered with using the discrete wavelet transformation. The Mallat multiresolution algorithm was used, which divides the signal using decomposition coefficients and a hard. This method was used for filtration of the neutron signals acquired from D-D fusion reaction at the device PF 1000 in IPPLM Warsaw. We present comparison of detected and reconstructed signals and a temporal evolution of neutron energy distribution for shot No. 6573.

Keywords: z-pinch, plasma-focus, wavelet transformation, neutron production.
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INTRODUCTION

The wavelet transformation is often used for signal smoothing and noise reduction. The wavelet transformation belongs to the integral transformations group and presents a better resolution both in time and frequency domain than for example the well known Fourier transform This tool can therefore be used to filter signals minimizing the signal losses.

In our work, the discrete wavelet transformation, Mallat algorithm and hard threshold function were used.

Discrete wavelet transformation may be explained [1] as a division of the signal to the high frequency and low frequency components. Dividing (decomposition) of the signals may be defined with the equations

$$S_{m+1}(k) = \sum_{p=1}^{N} h(p-2k) S_m(p)$$

$$T_{m+1}(k) = \sum_{p=1}^{N} g(p-2k) S_m(p)\,, \qquad (1)$$

where ***S***, ***T*** are decomposition coefficients, ***h***, ***g*** are so called decomposition filters, ***h*** is low-pass filter and ***g*** is a band-pass filter. The decomposition coefficients are multiplied with special function, actually the smaller coefficients are erased. The used hard threshold function is defined as

$$\hat{T}_{ij}^{hard} = \begin{cases} 0 : \left|T_{ij}\right| < T \\ T_{ij} : \left|T_{ij}\right| \geq T \end{cases}, \tag{2}$$

where T is numerical value of threshold, calculated as $T = C\sigma(T_i)$, σ is mean deviation of a vector T_i.

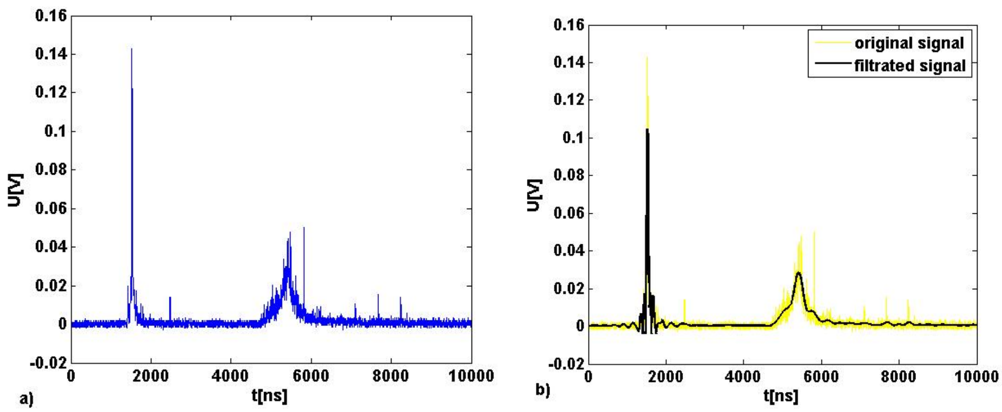


FIGURE 1: Shot 6573. Signal of the HXR and neutrons registered in distance 84 m downstream: a- measured, b- filtered.

EXPERIMENTAL AND DIAGNOSTIC SETUP

The measurements were performed at the PF 1000 facility [2], which operated at the electrical energy of 500 kJ, the voltage of 27 kV, and the maximum current at about 1.8 MA. We used the diagnostics similar to that described in [2]. Plastic scintillation probes of 5 cm thickness, equipped with fast photomultipliers detected the hard X-ray radiation (HXR) above a few hundred keV and neutron emission. The probes were situated downstream (at distances of 7.0 m, 16.3 m, 58.3 m and 84 m), upstream (at distances of 7.0 m, 16.3 m, 30.3 m, 44.2 m. 58.3 m and 84 m) and side-on (at distances of 7.0 m) and they were shielded again the scattered noise. For the neutron yield measurement, indium and silver activation counters were used.

EXPERIMENTAL RESULTS AND DISCUSSION

The presented results were obtained from the detail analysis of signals recorded in the shot No. 6573 with the total neutron yield 5×10^{10}. The signals were filtered using the wavelet transformation (discrete transformation, wavelet “discrete Meyer”). The time of production and energy distribution of neutrons were calculated using Monte-Carlo simulations and time-of-flight method.

In Fig. 1 one can compare signal of scintillation detector registered in distance 84m downstream) before and after filtration. The first short pulse corresponds to hard X-rays (HRX), and the second pulse represents the neutron signal. The sources of noise are mostly induced current in electronic circuits and cables, thermal noise of the circuits and low resolution of the scintillators.

In Fig. 2 we can compare detected and reconstructed signals of all detectors for both a- original and b- filtered signals. Signals were reconstructed using of Monte-Carlo algorithm and the percentage of reconstruction in the signals is approximate 80-90%. The cover of the relevant signals for filtered input is slightly better, but the main advantage of the filtration is a much better localization of the neutron energy distribution in time and energy (Fig. 3(A), 3(B) and Fig. 4).

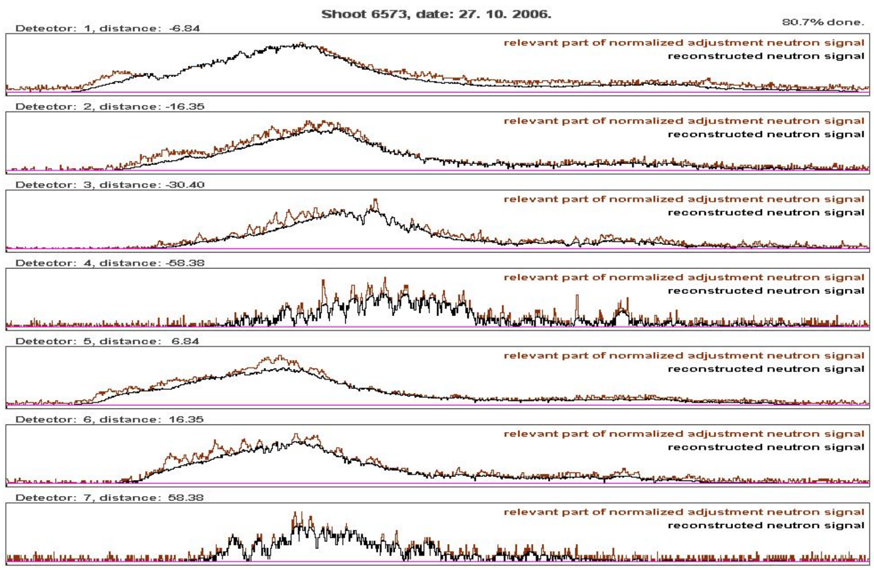


FIGURE 2 A : Shot 6573: Detected and reconstructed signals without filtration

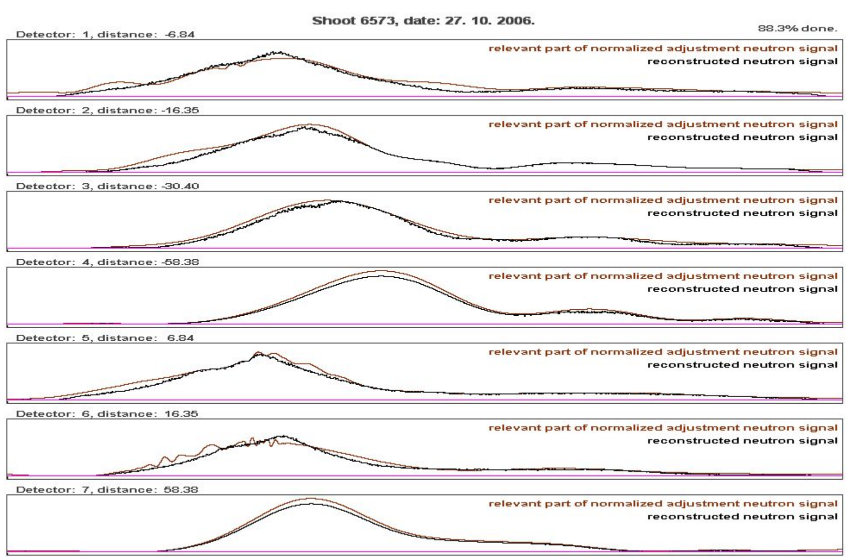


FIGURE 2 (B) : Shot 6573: detected and reconstructed signals with filtration

In Fig. 4 the energy distribution of neutrons is imaged for original and filtered signals as well. Dominant part of deuterons producing neutrons had the axial component of their velocity downstream.

In Fig. 3 a 4 one can compare the temporal evolution of neutron energy after reconstruction for a) original signals and b) filtered signals.

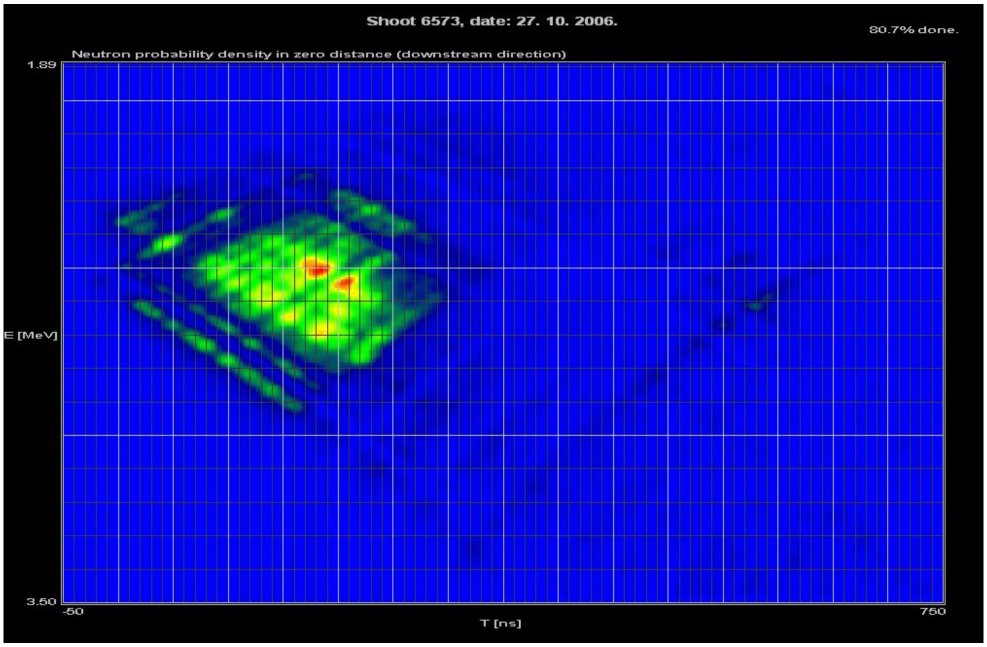


FIGURE 3 A : Shot 6573: Temporal evolution of neutron energy after reconstruction for original signals.

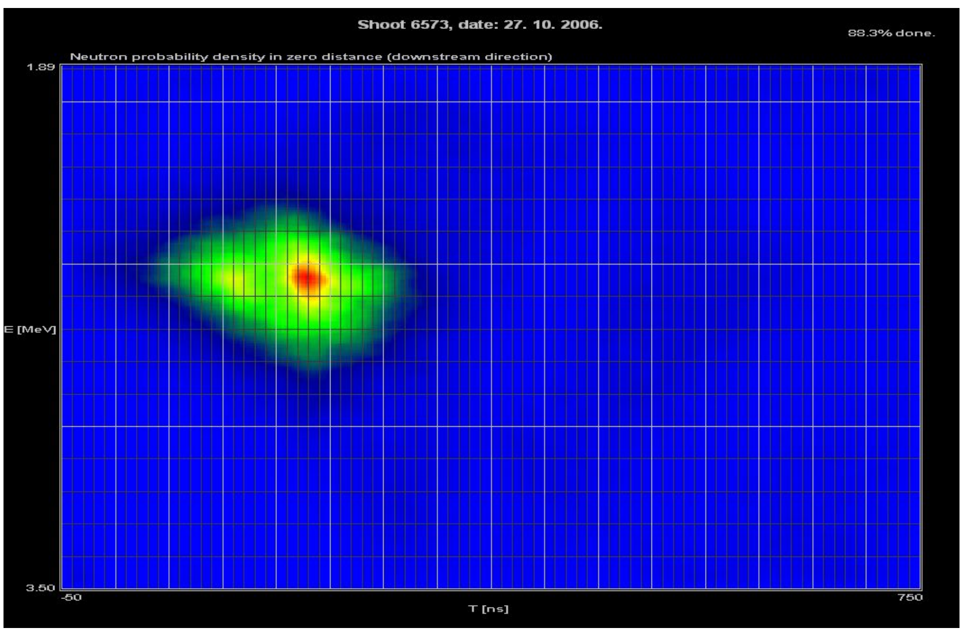
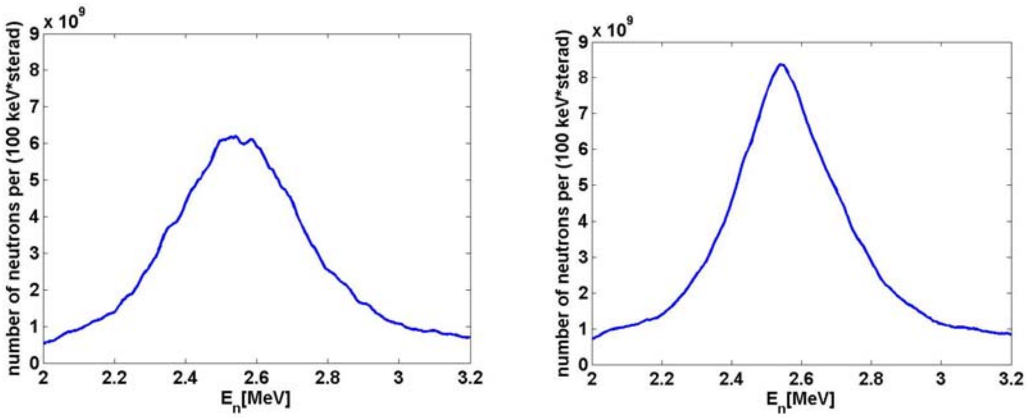


FIGURE 3 B : Shot 6573: Temporal evolution of neutron energy after reconstruction for filtered signals.



A. **B.**

FIGURE 4 : Energy distribution of neutrons in the direction downstream for A) original and B) filtered signals

CONCLUSIONS

In this paper we compare the influence of filtration of neutron signals on the accuracy of the determination of the energy spectra temporal distribution. The results can be summarized as follows:

- The maximum number of neutrons, detected downstream has energy 2.54 MeV in the downstream direction for both original and filtered signal.
- The maximum number of neutrons in filtered signal is 20% higher, than the original one.
- The full width half maximum for filtered signal is 0.173 MeV, 0.218 MeV for original signal, so about 20% lower.
- The main advantage of filtration of the signals is the much better localization of the number of neutrons maximum in energy and in time.

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