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Online neutron fluence measurement at University Hospital Essen neutron therapy facility using gallium arsenide LEDs

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ABSTRACT

The detector and sensor group of the West German Proton Therapy Centre (WPE) has developed a novel real-time neutron fluence monitor based on tiny, inexpensive, commercially available GaAs-LEDs. The linear detection range for d(14)+Be neutrons was evaluated to be 5.0×10^8–2.0×10^{11} neutron.cm^{-2}. However, this monitor can be used universally for neutrons of any energy distribution. Using scaling factors, fluence calibration curves for 1 MeV and 14 MeV D+T fusion neutrons have been calculated. The sensitivity of the detector increases with increasing neutron energy. This makes it suitable for the detection of high-energy neutrons, providing an extra advantage for use at a proton therapy facility where there is a high proportion of high-energy neutrons. The detector is practically not sensitive to photons. A prototype of the online GaAs-LED based neutron fluence monitor has been tested successfully at University Hospital Essen neutron therapy facility and will be implemented at WPE in the near future.

1. Introduction

The West German Proton Therapy Centre Essen (WPE) is expected to start clinical operation in 2011. Its detector and sensor group is developing devices which are not available commercially, however could be necessary or desirable for the determination of all aspects connected with the operation of a proton therapy facility. In that framework also an online neutron fluence monitor has been developed. The neutron fluence monitor has been tested at University Hospital Essen neutron therapy facility. Since 1972, the Strahlenklinik of the University Hospital Essen is operating this neutron therapy facility based on a TCC CV28 medical cyclotron. Neutrons of an average energy of 6 MeV are produced via [d(14)+Be] reaction by bombarding a thick beryllium target with 14 MeV deuterons (Rassow et al., 1978). The patient treatment at the facility has now been laid off. However, the neutron facility is further used for radiobiology experiments and collaborative research projects with the detector and sensor group of the neighbouring West German Proton Therapy Centre Essen (WPE) in the fields of radiation measurement, dosimetry and instrumentation.

2. The GaAs-LED based neutron fluence monitor developed by detector and sensor group

Fast neutrons interact with semiconductor materials dislodging the lattice atoms from their original stable positions, thereby creating vacancies. The combinations of vacancies and interstitial atoms are known as Frenkel-pairs. Displacement damage caused due to non-ionising-energy-loss (NIEL) of fast neutrons in bulk Gallium Arsenide (GaAs) light emitting diodes (LED) results in the reduction of their light output (Bates et al., 1997). The neutron energy dissipation in the LED is an explicit function of the kerma in GaAs and independent of neutron energy spectrum (Williams et al., 1994). Accompanying photons have practically no influence on the light output (Mukherjee et al., 2007). We have used this phenomenon to construct a fluence monitor for high-energy neutrons.

Usually, single LEDs with known light emission are irradiated in a neutron field and the reduction of the light emission is determined offline after the irradiation. We developed an online monitor enabling the light reduction be seen immediately. The circuit diagram of the monitor is given in Fig. 1. A bulk yellow GaAs-LED LED2 (Type: LN48YPX, Manufacturer: Panasonics Corporation,

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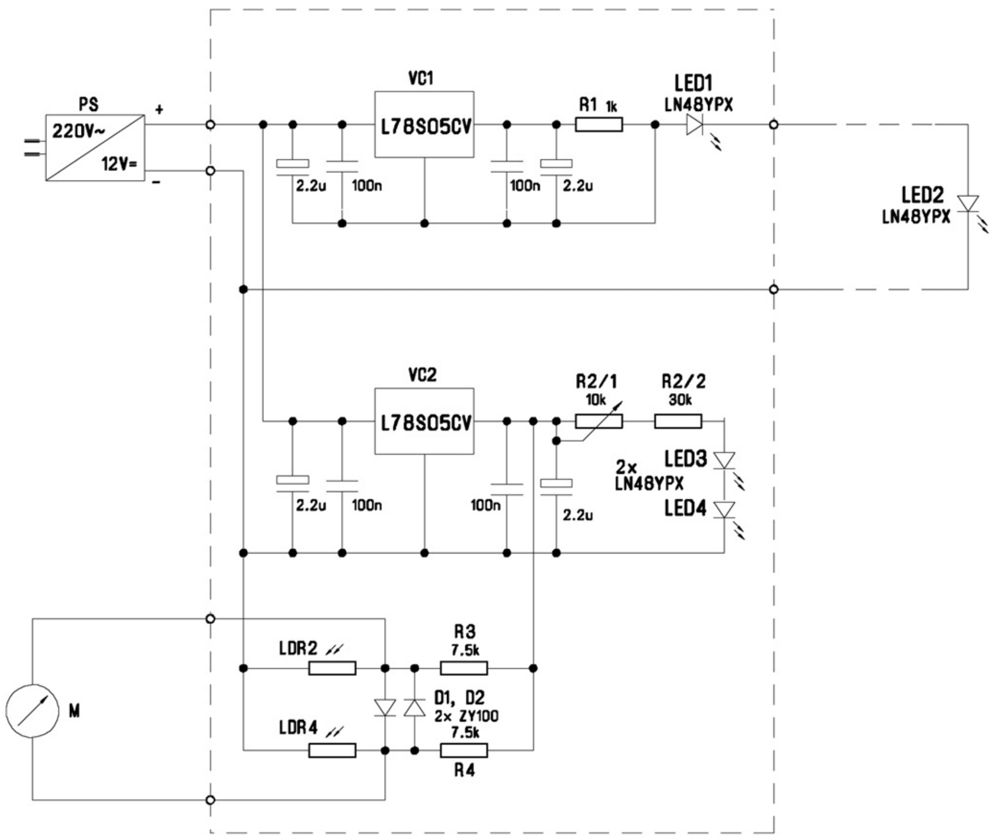

Fig. 1. Circuit diagram of the GaAs-LED based neutron monitor.

Japan) is the sensitive element of the neutron monitor. The sensor diode LED2 is connected to a constant current supply made with the fixed-voltage regulator VC1. The diode light output is fed to the light-dependent-resistor LDR2 via an optical fibre. The resistance of LDR2 is compared to that of an identical light-dependent-resistor LDR4 in a Wheatstone bridge. LDR4 is irradiated by light emitted from diode LED4, in such a way that the Wheatstone bridge is balanced. Therefore, the light output of LED4 can be regulated by voltage controller VC2. Diodes LED1 and LED3 signalise the correct function of LED2 and LED4 respectively. The measuring device M is a common digital multimeter with a resolution of 1 μV and data-logging function. The monitor is supplied by an AC adapter PS delivering 12 V DC.

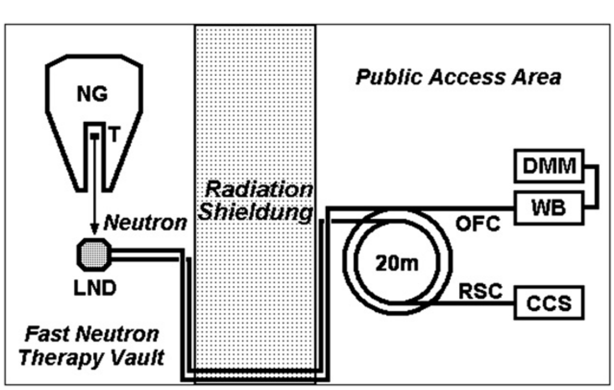

Fig. 2. Schematic setup of the real-time neutron fluence monitoring experiment.

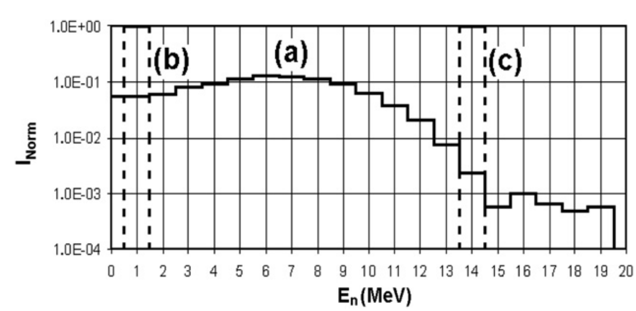

Fig. 3. Monte Carlo calculated neutron spectrum from [d(14)+Be] reaction (a), in addition line spectra of 1 MeV neutrons (b) and 14 MeV D+T fusion neutrons (c).

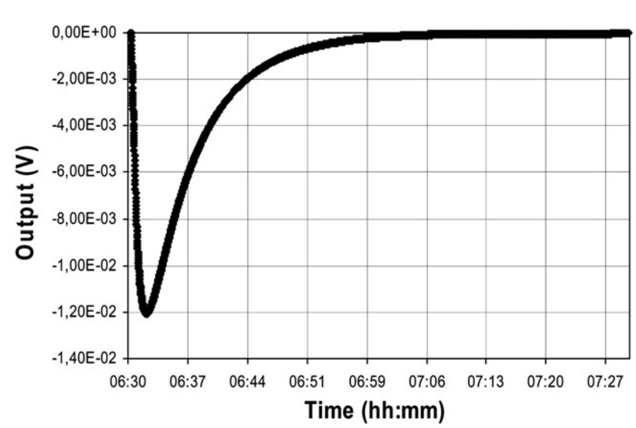

Fig. 4. Warm-up behaviour of the GaAs-LED based neutron fluence monitor.