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Novel design concepts for generating intense accelerator based beams of mono-energetic fast neutrons.

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Successful application of neutron techniques in research, medicine and industry depends on the availability of suitable neutron sources. This is particularly important for techniques that require mono-energetic fast neutrons with well defined energy spread. There are a limited number of nuclear reactions available for neutron production and often the reaction yield is low, particularly for thin targets required for the production of mono-energetic neutron beams. Moreover, desired target materials are often in a gaseous form, such as the reactions $D(d,n)^3He$ and $T(d,n)^4He$, requiring innovative design of targets, with sufficient target pressure and particle beam handling capability. Additional requirements, particularly important in industrial applications, and for research institutions with limited funds, are the cost effectiveness as well as small size, coupled with reliable and continuous operation of the system. Neutron sources based on high-power, compact radio-frequency quadrupole (RFQ) linacs can satisfy these criteria, if used with a suitable target system.

This paper discusses the characteristics of a deuteron RFQ linear accelerator system coupled to a high pressure differentially pumped deuterium target. Such a source, provides in excess of 10^{10} mono-energetic neutrons per second with minimal slow neutron and gamma-ray contamination, and is utilised for a variety of applications in the field of mineral identification and materials diagnostics. There is also the possibility of utilising a proposed enhanced system for isotope production.

The RFQ linear accelerator consists of:
1) Deuterium 25 keV ion source injector
2) Two close-coupled RFQ resonators, each powered by an rf amplifier supplying up to 300 kW of peak power at 425 MHz.
3) High energy beam transport system consisting of a beam line, a toroid for beam current monitoring, two steering magnets and a quadrupole triplet for beam focusing.

Basic technical specifications of the RFQ linac are presented elsewhere [1].

In the case of an RFQ accelerator, operating in a pulsed bunched mode, a suitable shutter mechanism can be used to effectively isolate the gas target between beam pulses and thus considerably reduce the gas load on a differentially pumped system whilst still maintaining the target at pressures up to ~1.2 bar. Such a system operating on a 2% duty cycle RFQ system has been implemented [2]. To go to even higher gas pressure or higher accelerator duty cycle, further improvements to the gas target system, in the form of a plasma window, have been investigated and are being implemented [3].

The RFQ linear accelerator presently utilised delivers a maximum average beam current of 100 μA of 3.6-4.9 MeV deuterons, dependent on the phase coupling between the two accelerating cavities. In a 30 mm long deuterium gas cell, operating at a pressure of 1.2 bar, the expected neutron emission is $\sim 10^{10}\ s^{-1}$, into the full solid angle. A maximum neutron energy obtained in the reaction $D(d,n)^3He$ would be 8.1 MeV with the spread of ~750 keV.

Due to kinematics, approximately 50% of the primary neutron beam is emitted into a 20^{o} forward cone. This translates to the expected neutron densities in excess of 10^7 n. s^{-1} cm^{-2} some 10-20 cm away from the gas cell. Beam quality is high, with the slow neutron and gamma-ray components below 10% of the total primary fast neutron beam [2]. The fast neutron energy spread (and the total neutron output) can be tailored to a specific application by adjusting either the gas cell length or the target gas pressure.

The robust design and reasonable cost make the described neutron source a very attractive choice for variety of applications, such as mineral identification, material diagnostics (complementing thermal neutron radiography), and isotope generation. These activities are currently being pursued at NECSA along with close collaboration with academic institutions and industry.

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