Current Status of R&D of the Humanitarian Landmine Detection System by a Compact Fusion Neutron Source

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Current results are presented on the research and development of the advanced humanitarian landmine detection system by using a compact discharge-type fusion neutron source called IECF (Inertial-Electrostatic Confinement fusion) devices. A water-jacketed IEC device (IEC20C) of a 20 cm inner diameter is operated to produce $10^7$ neutrons/s stably in CW mode for 80 kV and 80 mA. Ample 10.8 MeV $\gamma$ rays produced through $(n, \gamma)$ reaction with nitrogen atoms in the melamine ($C_3H_6N_6$) powder (explosive simulant) are clearly measured by a BGO-NaI-combined scintillation sensor with distinct difference in cases of with and without melamine.

1. Introduction

An IECF (Inertial-Electrostatic Confinement Fusion) device is an extremely compact, and simple device as is shown in Fig. 1, running by electrical discharge either on D-D, D-T or D-\textsuperscript{3}He fuel gases. It consists of a hollow cathode at the center of a spherical vacuum chamber serving as the anode. A glow discharge takes place between the anode and cathode as is seen in Fig. 1, thereby, producing ions that are accelerated toward the cathode center, and undergo fusion reactions through beam-beam collisions, or beam-background gas collisions (Fig. 2).

So far, D-D neutrons (2.45 MeV), and D-\textsuperscript{3}He protons (14.7 MeV) both in excess of $10^8$ n/s in CW mode at University of Wisconsin, Madison [1,2], and $6.8 \times 10^9$ D-D neutrons/s in pulsed mode at Tokyo Institute of Technology [3] were achieved.

This concept was first proposed in 1950’s, and Hirsch first made experiments and obtained record neutron output of approximately $10^8$ D-D neutrons/s, and $10^{10}$ D-T neutrons/s, respectively, in 1967 from a gridded IECF device driven by six ion guns [4].

After a long pause in the research, the present extremely simple new concept came out, and versatile industrial applications, such as, positron emitter production for cancer detection, boron neutron capture therapy (BNCT) for cancer treatment, and anti-personnel landmine identification are three representative present application candidates.

At present most of the humanitarian demining is done using conventional methods, such as, metal detectors, prodders, and/or dogs, making the procedure of destroying 60 million abandoned anti-personnel landmines (APL) very slow and dangerous, particularly for plastic landmines. Innovative methods are thus needed in order to speed up the process [5].

Since the explosives of landmines include such as C, H, N, O, and Cl elements in specific fractions, interaction with neutrons, such as, neutron backscatter, and neutron-induced $\gamma$-rays could be used as innovative methods for detection and identification of landmines. Neutron backscattering using radio-isotopic sources, such as $^{252}$Cf, or Am-Be, appears to be appropriate for the landmine problem but only for shallow arid soils [6–8]. Nuclear techniques by neutron-induced $\gamma$-rays us-
ing $^{252}\text{Cf}$ [9] or D-T tubes [10] appear to lack the required sensitivity for the effective detection of sub-kilogram quantities of explosives in AP landmines, particularly for deeply buried landmines, in addition to their relatively short life times of the sources and radioactive restrictions.

From this viewpoint, a D-D-driven IECF device could be an ideal neutron source with adequate intensity in both pulse and CW dual mode of operation. In addition to cheap, compact, and simple features, it has safety advantages over $^{252}\text{Cf}$, or Am-Be sources because the radiation goes away when the device is turned off. It does not need tritium that needs replacement often and has its own safety issues.

2. A New IECF Neutron Source with a Water Jacket

For the detection of landmines, a CW stable operation of the neutron source is essential. Also, the enhanced fusion neutron flux towards the ground is strongly preferred, although emission of fusion neutrons in the IECF device is basically isotropic.

To meet these requirements, a new advanced device (IEC20C) of a 20 cm inner diameter was manufactured as shown in Fig. 3, which has a 5 cm-thick water jacket over the upper part for both cooling and reflection of neutrons, while the nozzle facing the ground has 1 cm thick cooling channel. It is found that it can produce $10^7$ D-D neutrons/s stably in CW mode for 80 kV and 80 mA, and due to the thick water jacket, the neutron flux beneath the IEC exit nozzle with a relatively thinner 1 cm thick water jacket is found
to be beam-like with more than 2 times magnified flux [11].

3. 10.8 MeV $\gamma$-ray Diagnostics

A practical landmine detection system is being developed appropriate to all-plastic landmines, in particular, by detecting neutron capture $\gamma$-rays of 10.83 MeV emitted by nitrogen atoms to identify explosives (Fig. 4). For a well-collimated detection of the highly energetic $\gamma$-rays, a BGO-NaI (Bismuth-Germanium Oxide-Sodium Iodide)-combined scintillation sensor has also been developed. Preliminary experiments with an explosive simulant (melamine: $\text{C}_3\text{H}_6\text{N}_6$) have been performed to show promising and practical features for landmine detection as is shown in Fig. 5 [12], where the data include background $\gamma$-rays emitted by the soil elements, for example Si, in both cases.

Since the irradiated Si atoms are known to emit 10.6 MeV capture $\gamma$-rays, they may be observed as false signals in the vicinity of 10.8 MeV $\gamma$-rays by nitrogen atoms. However, since the emission probability of them by Si atoms is as low as 0.59% [13], it is well considered reasonably that the $\gamma$-rays by Si atoms may not show a sharp peak on this spectra. Actually, it is found in Fig. 5 that there is an obvious difference on the BGO en-
ergy spectra between the cases with and without the simulant (melamine) under the background $\gamma$-rays by various soil elements in both cases. With these successful results, outdoor field tests are being planned next February, 2007 in Japan.

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REFERENCES