Diamond detector telescopes for cyclotron beam identification

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This year, we have started a new development project to use diamond detectors for the identification of beams from the K500 and K150 cyclotrons. Diamond detectors have many advantages over traditional silicon detectors in that they are more radiation resilient, are low noise, and have intrinsically low leakage current. However, these detectors can only be made to cover relatively small area (typically less than 25 mm^2), and they also produce less signal than similar silicon detectors.

In the past, single crystal diamond detectors (scCVD) have mainly been used for fast timing applications such as high-resolution time-of-flight measurements [1]. Recently, with the wider availability of so-called "electronic-grade" single crystal diamond detectors, spectroscopic applications with high energy resolution have become possible. With this improved resolution, it is envisioned that two diamond detectors could be combined into a ΔE-E telescope configuration and employed to identify beams from the cyclotrons according to their energy loss. These diamond detector telescopes could then replace existing silicon telescopes currently used for beam identification at MARS [2] and elsewhere. They could also allow for beam identification at higher count rates, which is often not possible with silicon detectors without significantly damaging them

We have been developing a prototype diamond detector telescope for the Cyclotron Institute with Applied Diamond Inc. in Wilmington, Delaware, USA. The resulting detector has been received and is shown in Fig. 1. The detector is composed of a ΔE detector of 50 μm diamond and an E detector 500 μm diamond. Both detectors are scCVD, have 16 mm^2 active area, and Cr-Au pad metallization.

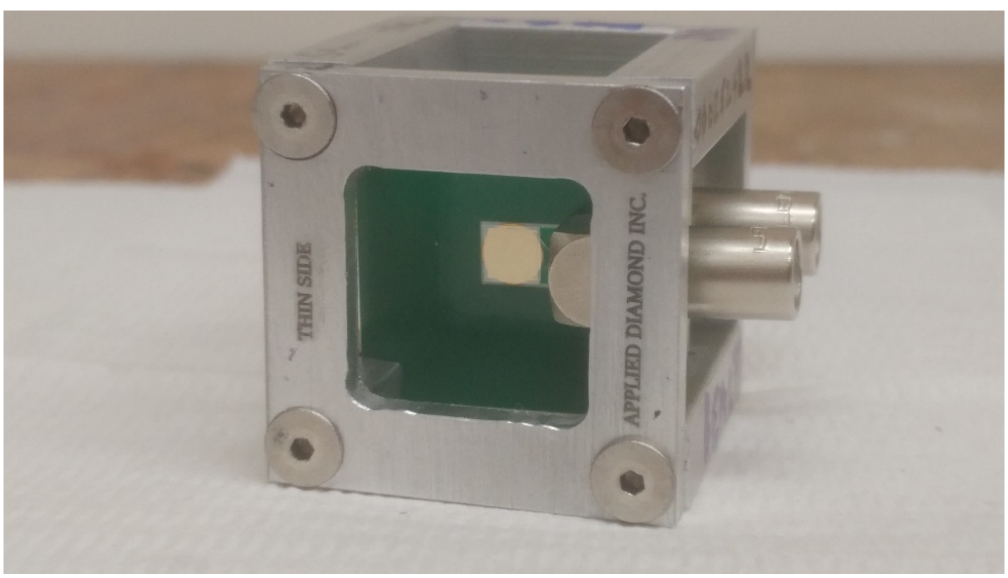

Fig. 1. The diamond telescope assembly, produced by Applied Diamond Inc. The entire assembly is about 1 in^3 in volume. See text for further explanation.

The detector was tested with a ^{228}Th alpha source to measure the resolution of the individual detectors in the telescope. To obtain the best resolution, the combination of an Ortec 142A charge-sensitive preamplifier and a CAEN DT-5780 desktop digitizer was employed. Special care was also taken to reduce electronic noise by minimizing the cable lengths, especially between the vacuum flange and the preamplifier input. A typical spectrum from the diamond detector tests with the ^{228}Th source is shown in Fig. 2. A peak resolution of better than 80 keV FWHM, or about 1.5%, was obtained.

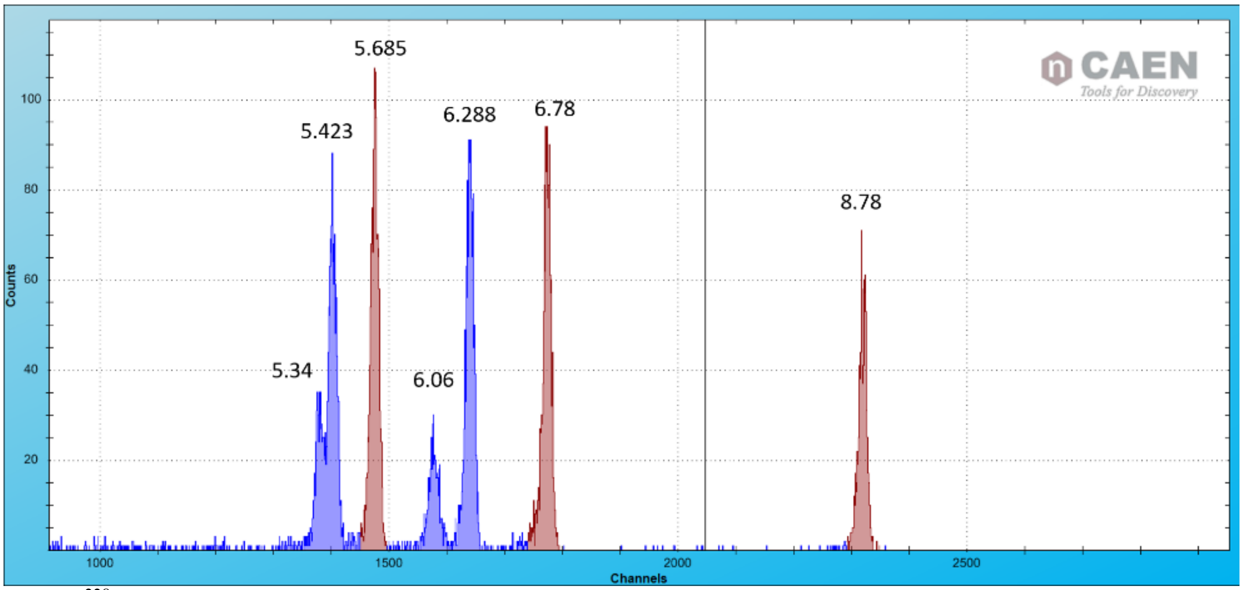

Fig. 2. ^{228}Th alpha source spectrum obtained with the 50μm thick diamond detector. The resolution obtained was about 1.5% FWHM. Peak labels shown are the alpha particle energies in MeV. See text for further explanation.

In the coming year, this diamond telescope will be tested with beams from the K150 and K500 cyclotrons. As the Ortec 142A preamps saturate for energy deposits above 200 MeV, lower gain, higher range CAEN model 1422A preamps have been purchased for measuring higher mass and higher energy beams. Once tested, the diamond telescope will have applications in verifying the beam purity for the SEE line, identifying the re-accelerated beams for the Light Ion Guide, and in tuning rare isotope beams with MARS.

[1] S. Michimasa *et al.*, Nucl. Instrum. Methods Phys. Res. **B317**, 710 (2013).
[2] R.E. Tribble, R.H. Burch, and C.A. Gagliardi, Nucl. Instrum. Methods Phys. Res. **A285**, 441 (1989).