# Portable Gamma Detector for G20

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# Single Crystal Growth of NaI:Tl and Fabrication of Gamma Detector for Field Application

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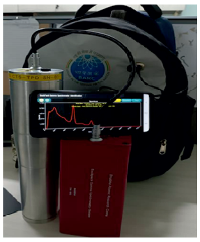

*The NaI:Tl detector assembly with the Backpack Gamma Spectrometer System*

ABSTRACT

Thallium-doped Sodium Iodide (NaI:Tl), a widely used scintillator material, is commercially available and extensively employed across various departments. In pursuit of detector technology self-reliance, we successfully grew a 2”x2” NaI:Tl single crystal and assembled it with a photomultiplier tube (PMT), compatible preamplifier, and hermetically sealed aluminum housing. Signal processing utilized the indigenously developed Backpack Gamma Spectrometer System (BGSS) at BARC. Rigorous lab and field testing confirmed the detector’s characteristics comparable to commercial counterparts, demonstrating its suitability for radiation detection. This DAE in-house made detector was further deployed at the G-20 summit venue for the radiation surveillance.

KEYWORDS: *Gamma Detector, Scintillator, Sodium Iodide (NaI:Tl), Single crystal, Gamma spectroscopy, Photo multiplier tube (PMT), Radiation detector*

## Introduction

Scintillators are materials designed to detect high-energy photons and particles, including alpha particles, electrons, and neutrons [1]. They encompass a range of materials such as inorganic and organic crystals, organic liquids, noble gases, and scintillating gases [2]. These materials play a crucial role in converting absorbed energy into visible or ultraviolet photons, enabling detection by photomultipliers and photodiodes [3]. Moreover, scintillators facilitate the accurate measurement of incident radiation's energy and time. Compared to other radiation detectors, they offer enhanced sensitivity to deposited energy, faster response times, and simpler, reliable, and cost-effective construction and operation. Consequently, scintillators find extensive applications in diverse fields such as nuclear plants, medical imaging, manufacturing industries, high-energy particle experiments, and national security [4]. With the years, the demand for scintillators is increasing across the globe. The global scintillator market has witnessed substantial growth in recent years, with its size reaching approximately US$ 540 million in 2022. According to projections by IMARC Group, the market is anticipated to expand further and reach around US$ 715 million by 2028. This implies a compound annual growth rate (CAGR) of 4.7% during the period from 2023 to 2028 [5].

NaI:Tl scintillators have a proven track record of reliability and cost-effectiveness, making them indispensable tools in the field of radiation detection and imaging for nuclear physics, medical imaging, and environmental monitoring [6]. Their exceptional performance and broad range of applications have established them as a key choice for commercial customers seeking accurate and efficient solutions for radiation measurement [7]. However, despite its commercial availability, the Department of Atomic Energy (DAE) in India heavily relies on imports of NaI detectors. To enhance self-reliance in detector technology, a team of researchers from Bhabha Atomic Research Centre (BARC) in Mumbai successfully grew a 2” x 2” single crystal of NaI:Tl and developed a complete detector assembly for radiation detection. This report presents the details of the single crystal growth process, detector fabrication, and the performance evaluation of the indigenously developed gamma detector.

The single crystals of NaI:Tl were grown in a quartz crucible using the Bridgman-Stockbarger technique [8]. The quartz crucibles were thoroughly cleaned and loaded with high-purity NaI and TlI powders. The material was initially dehydrated and sealed. Then the crucible was placed in the Bridgman crystal growth system with controlled heating zones, allowing for the formation of a desired temperature gradient. The temperature of the furnace is increased to melt CsI and after thermalization the crucible is slowly translated to a lower temperature zone for slow and controlled solidification. The grown crystals is taken out of the crucible and were cut, polished, and mounted on photomultiplier tubes (PMTs) using transparent optical cement. The single crystals of NaI:Tl obtained through the growth process were crack-free, transparent, and without inclusions. The crystals were successfully cut and polished into a size of 2” x 2”. The mounting of NaI crystals on PMTs was performed with great care to achieve effective optical coupling and prevent air gaps or bubbles. The hermetic sealing of the crystal-PMT assemblies inside aluminum casings provided mechanical support and ensured the integrity of the detectors.

Functional testing of the NaI:Tl detectors was carried out at both laboratory and field conditions. The detectors were connected to the Backpack Gamma Spectrometer System (BGSS), an indigenously developed signal processing system

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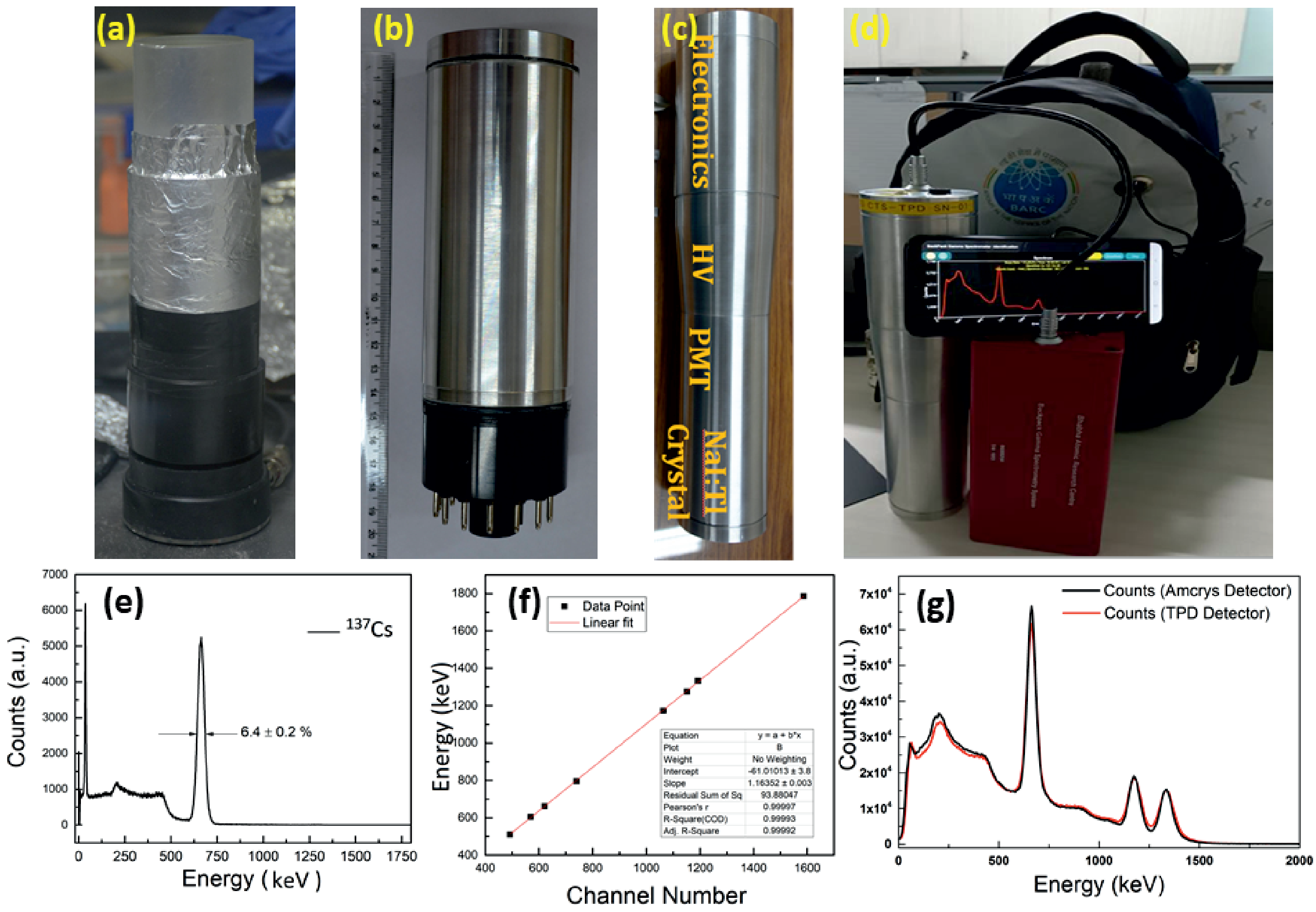


*Fig.1: (a) Photograph of the grown crystal mounted on the PMT, (b) Hermetic sealing of the crystal with PMT, (c) the detector assembly, (d) The NaI:Tl detector assembly with the Backpack Gamma Spectrometer System, (e) pulse height spectra for 137Cs source measured using the NaI:Tl based BGSS, (f) Linearity of the detector assembly from 511keV to 1.7 Mev, (g) comparison of the indigenous detector assembly with commercially available Amcrys make detector.*

by RSSD, BARC [9]. The detectors exhibited a linear response in the energy range of 500-1800 keV and demonstrated excellent energy resolution. The typical resolution calculated at 662 keV was found to be 6.5 ± 0.2%, comparable to commercial NaI detectors. The stability of the gamma spectrum was evaluated by continuously operating the BGSS system for extended periods, showing no shift in pulse height or change in energy resolution.

The performance of the indigenously developed NaI:Tl detectors was compared with commercially available 2” x 2” size NaI:Tl detectors from Amcrys. The response, resolution, and pulse height of the indigenous detectors were found to be well-matched with the commercial detectors, indicating their comparable performance. 15 such detectors were developed for radiation surveillance at G-20 summit by DAE.

This technological development reduces the department’s dependence on imported detectors and also contributes to self-reliance in the Department of Atomic Energy in India as a step towards Atmanirbhar Bharat.

## Conclusion

The successful growth of a 2” x 2” NaI:Tl single crystal was achieved indigenously Bridgman-Stockbarger technique to reduce India’s reliance on imported radiation detectors. The crack-free crystals were mounted on photomultiplier tubes with hermetic sealing. After connecting to the BGSS, all calibration tests exhibited an excellent energy resolution (6.5 ± 0.2% at 662 keV) and stability. Comparison with commercial counterparts confirmed comparable performance hence leading to the deployment of 15 detectors for G-20 summit radiation surveillance an impactful stride towards Atmanirbhar Bharat in the Department of Atomic Energy.

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