2026 JULY 19–22
VANCOUVER, BC
JOINT AAPM | COMP MEETING

Evaluation of Plastic Scintillation Detectors for Quality Assurance in Non-Coplanar Stereotactic Radiotherapy

Shuichi Ozawa[a,b,c], Yuki Hoshi[d], Yoshitaka Oka[d]

[a] Hiroshima High-Precision Radiotherapy Cancer Center,
[b] Hiroshima University, Graduate School of Biomedical and Health Sciences, [c] RTQM System Inc.,
[d] Fukushima Medical University Hospital

ABSTRACT

Purpose: Non-coplanar arc irradiation is widely used in stereotactic radiotherapy to achieve highly conformal dose distributions for small targets. For patient-specific quality assurance (PSQA), detector performance must remain stable under continuous gantry rotation and varying couch angles. This study evaluated the suitability of a plastic scintillation detector (PSD) system for PSQA under clinically relevant non-coplanar stereotactic irradiation conditions.

Methods: QA measurements were performed using PSQA-like verification plans with a PSD system (Model 10, Blue Physics) and a PinPoint ionization chamber (PTW 31016) as a reference. A fixed square field size of 2 × 2 cm² was used with 6 MV flattening-filter-free (FFF) photon beams delivered by a Varian TrueBeam STx. Non-coplanar conformal arc irradiation was delivered with gantry rotation from 0 to 179 degrees and couch angles of 0, 30, 60, and 90 degrees, resulting in four arc deliveries. The prescribed dose of 10 Gy was defined at the phantom center, corresponding to the linac isocenter, where both the PSD and ionization chamber were positioned. Measurements were performed using a spherical phantom with detectors positioned at the isocenter. Measured doses were compared with treatment planning system (TPS) calculations (Varian Eclipse, Acuros XB).

Results: The maximum absolute deviations from TPS were 0.69% for the Model 10 and 0.52% for the PTW 31016. The maximum separation between the two detectors was 1.21 percentage points at couch 90°. No systematic couch-angle dependence was observed during continuous gantry rotation.

Conclusion: Under the evaluated conformal-arc conditions, the Model 10 demonstrated accurate and stable dosimetric performance, supporting its feasibility for non-coplanar stereotactic PSQA.

CONTACT

Shuichi Ozawa, PhD, DABR
Hiroshima High-Precision Radiotherapy Cancer Center
3-2-2 Futabanosato, Higashi-ku, Hiroshima 732-0057, JAPAN
ozawa@hiprac.jp

Conflict of Interest: S. Ozawa is Founder and CEO of RTQM System Inc.; other authors declare no conflicts of interest.

INTRODUCTION

Non-coplanar stereotactic radiotherapy (SRT) is widely employed to achieve highly conformal dose distributions for small targets while sparing surrounding normal tissues. Accurate patient-specific quality assurance (PSQA) is therefore essential before treatment delivery [1].

Plastic scintillation detectors (PSDs) provide excellent spatial resolution, water equivalence, and near energy independence [3,4], making them attractive for small-field dosimetry [2]. However, during non-coplanar arc irradiation, the volume of transport optical fiber irradiated by the beam varies with couch and gantry angles, altering the amount of generated Cherenkov light. Reliable removal of this Cherenkov component is therefore critical for accurate dose measurement [3,4].

The purpose of this study was to evaluate the clinical applicability of a dual-channel Model 10 PSD system (Blue Physics) [4] for PSQA under clinically relevant non-coplanar stereotactic irradiation conditions.

METHODS AND MATERIALS

Detector System

- Model 10 PSD (Blue Physics); scintillator dimensions: 1 mm diameter × 1 mm length
- Reference detector: PTW 31016 PinPoint 3D ionization chamber

Cherenkov Correction

The Cherenkov component was corrected using

$$R_{PSD} = R_S - (R_C \times ACR)$$

where

R_{PSD} : corrected signal proportional to the absorbed dose measured by the PSD
R_S : PSD + Cherenkov signal (Ch0)
R_C : Cherenkov signal (Ch1)
ACR : Adjacent Channel Ratio

The Cherenkov-corrected, dose-proportional PSD signal was calculated using the dual-channel subtraction method [4]. The ACR was measured before the PSQA measurements and held constant for all four deliveries.

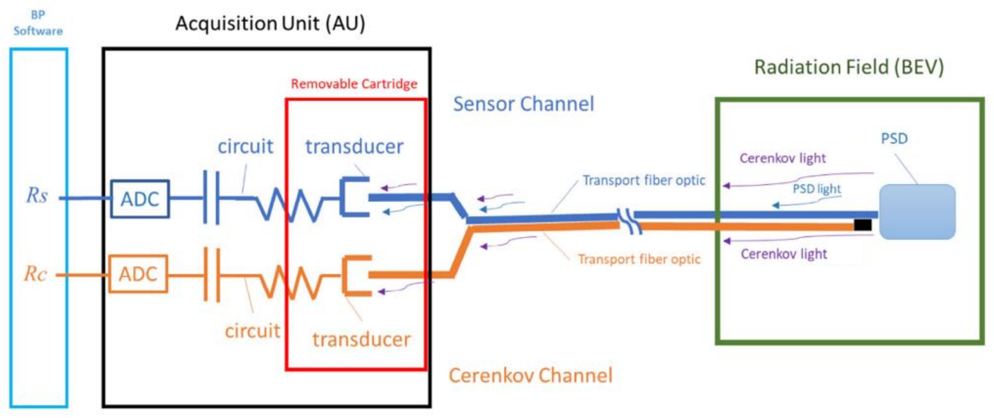

Figure 1. Schematic of the dual-channel Model 10 PSD system used for Cherenkov subtraction.

Irradiation Parameters

Table 1. Irradiation and measurement parameters.

Parameter	Value
Linac	Varian TrueBeam STx
Beam	6 MV FFF
Dose rate	1400 MU/min
Field size	2 × 2 cm² (fixed MLC-defined field)
Phantom	Spherical phantom (20 cm diameter)
Prescription	10 Gy at isocenter
Gantry rotation	0 – 179° (Conformal arc)
Couch angles	0°, 30°, 60°, 90°
TPS	Eclipse 18.1 (Acuros XB)

Non-Coplanar Irradiation Setup

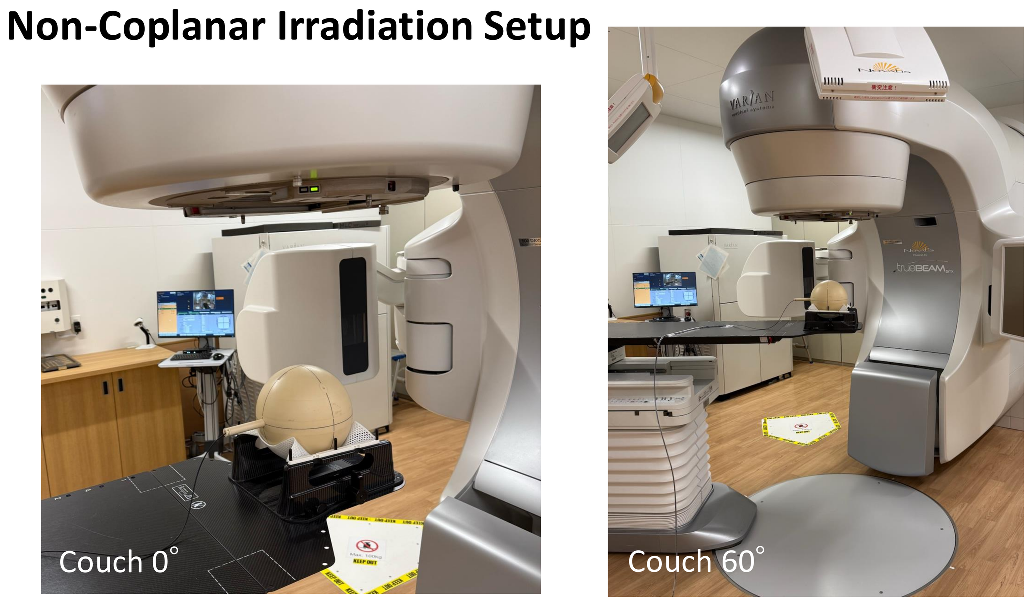

Figure 2. Non-coplanar arc setup at couch angles of 0° (left) and 60° (right). Couch angle determines the beam–fiber geometry; during arc delivery, gantry rotation changes the volume of transport optical fiber irradiated by the beam, thereby altering the Cherenkov contribution.

RESULTS

Signal Stability

Figure 3 shows the Ch0 and Ch1 signals acquired during each non-coplanar arc. Although the volume of transport optical fiber irradiated by the beam varied with couch and gantry angles, dual-channel correction removed the Cherenkov-light contribution and yielded a stable dose-proportional PSD signal.

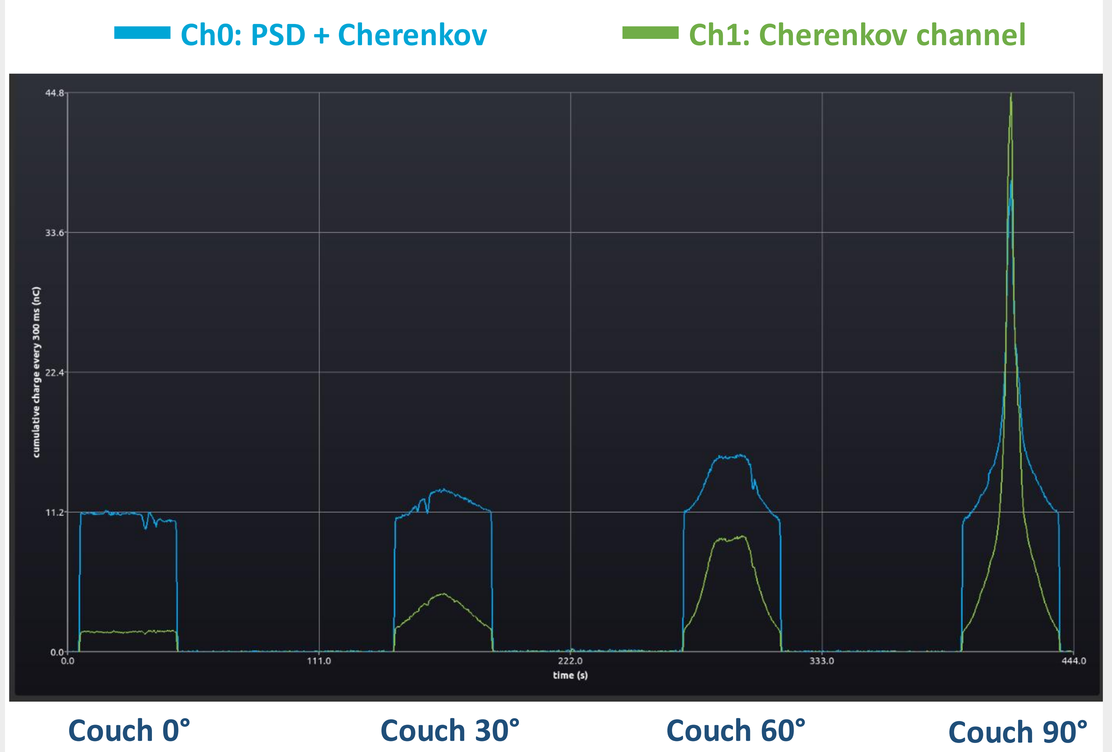

Figure 3. shows couch- and gantry-angle-dependent variations in the raw Ch0 and Ch1 signals. After dual-channel Cherenkov subtraction, the Model 10 dose differed from TPS by no more than 0.69% at any evaluated couch angle (Fig. 4).

Dose Accuracy

Both detectors were within ±1% of TPS at all evaluated couch angles. The maximum separation between the Model 10 PSD and PTW 31016 PinPoint chamber was approximately 1.21 percentage points at couch 90° (Fig. 4).

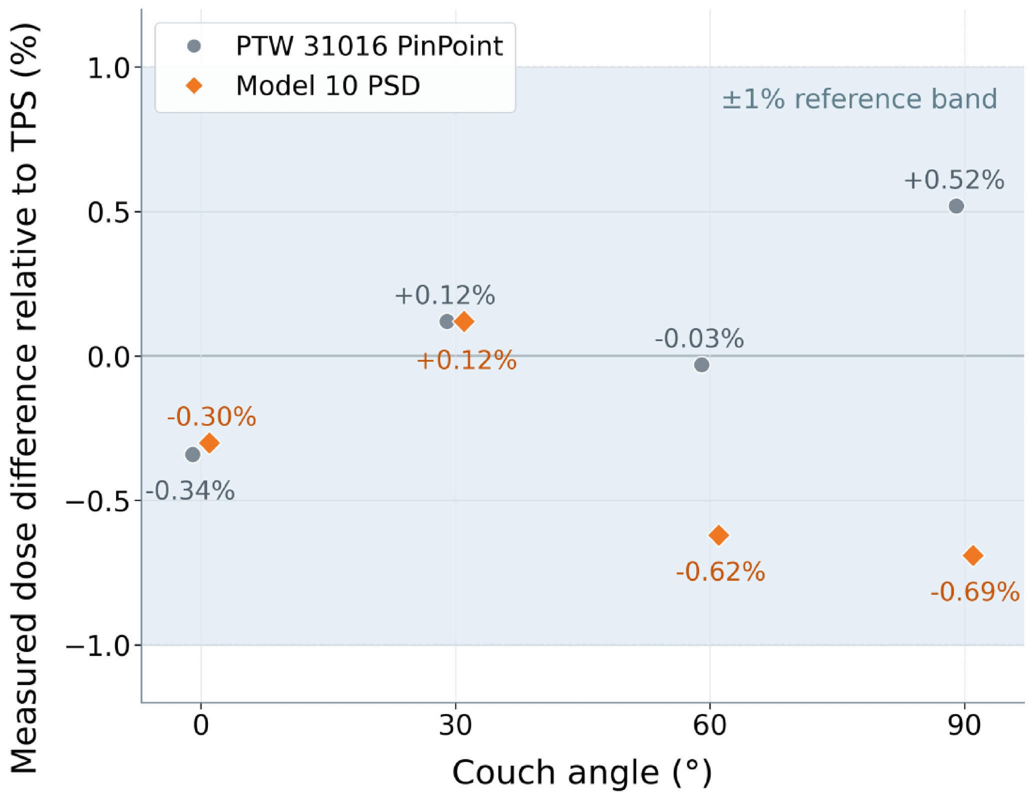

Figure 4. Dose differences relative to TPS for the PTW 31016 PinPoint chamber and Model 10 PSD. Absolute detector-to-TPS deviations were ≤0.52% and ≤0.69%, respectively.

DISCUSSION

The Model 10 PSD maintained dosimetric accuracy under challenging non-coplanar irradiation conditions.

Couch rotation changes the beam–fiber geometry and the volume of transport optical fiber irradiated during arc delivery, altering the Cherenkov contribution. Dual-channel correction compensated for this variation and maintained a consistent dose response.

These findings support the feasibility of using the detector for PSQA of stereotactic treatments involving multiple couch angles and small fields.

Relevant PSD characteristics for PSQA [3,4] include:

- real-time measurement
- excellent spatial resolution
- minimal energy dependence
- applicability to stereotactic QA workflows

CONCLUSIONS

- A dual-channel Model 10 PSD system was evaluated under non-coplanar conformal-arc irradiation at four couch angles.
- Cherenkov subtraction remained effective despite couch- and gantry-angle-dependent changes in the irradiated transport-fiber volume.
- The maximum absolute deviations from TPS were 0.69% for the Model 10 and 0.52% for the PTW 31016; the maximum detector-to-detector separation was 1.21 percentage points.
- Under the evaluated conditions, these results support the feasibility of the Model 10 for non-coplanar stereotactic PSQA.

Future work:

- Extend evaluation to circular cones, MLC-based non-coplanar arcs, multi-target plans, and end-to-end PSQA workflows.
- Assess calibration robustness across phantom setups and clinical plan complexity.

KEY FINDINGS

✓ Effective Cherenkov subtraction across all couch angles
✓ Model 10–TPS deviation ≤0.69%
✓ PTW 31016–TPS deviation ≤0.52%
✓ Supports feasibility for non-coplanar stereotactic PSQA

REFERENCES

1. Miften et al. Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No. 218. Med Phys. 2018;45:e53–e83.
2. Palmans et al. Dosimetry of small static fields used in external photon beam radiotherapy: Summary of TRS-483, the IAEA–AAPM international Code of Practice for reference and relative dose determination. Med Phys. 2018;45:e1123–e1145.
3. Beddar et al. Water-equivalent plastic scintillation detectors for high-energy beam dosimetry: I. Physical characteristics and theoretical considerations. Phys Med Biol. 1992;37:1883–1900.
4. Das et al. Characteristics of a plastic scintillation detector in photon beam dosimetry. J Appl Clin Med Phys. 2024;25:e14209. doi:10.1002/acm2.14209.