Dosimetry for Balloon-based Radiation Therapy

Workshop on Opportunities with Detector Technologies in Nuclear Physics

Catholic University of America
January 2018

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(with help from Steve Gelmine, Radiadyne)

Balloon use in External Beam Radiation Therapy

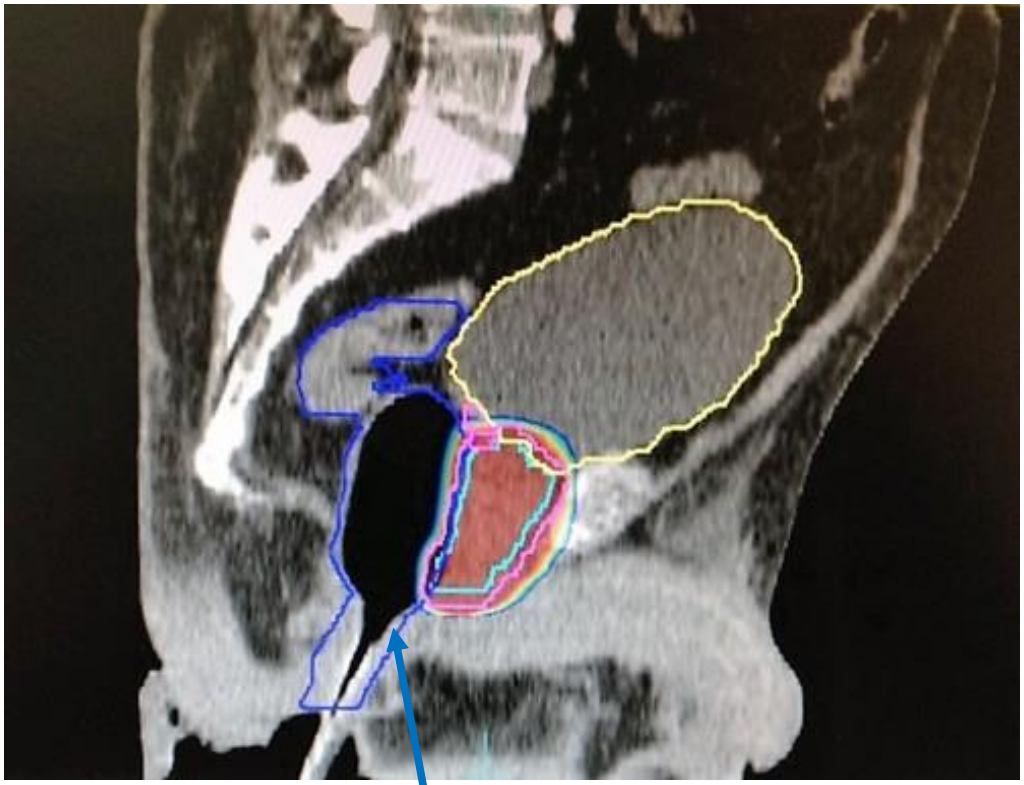
Over 50% of (USA) cancer patients receive radiation treatment for localized disease sites, mostly delivered via an external beam (X-ray, proton,..)

Patient immobilization can be critical –
internal structures as well!

How to accomplish this?....

Example: Endorectal Immobilization and Positioning

- Immobilizes the prostate
- Reduces movement variation between treatments
- Displaces posterior and superior rectum away from the field
- Reduce rectal toxicity by decreasing the volume of the rectal wall being irradiated
- May allow for physicians to reduce PTV/treatment margins
- Facilitates dose escalation/hypofractionated treatments
- Is well tolerated by prostate patients



Balloon use in Brachytherapy

”Brachy” = near, short distance: **Internal**

Radioactive seeds or sources are placed in or near the tumor, delivering a high radiation dose to the tumor while reducing the radiation exposure to surrounding healthy tissues.

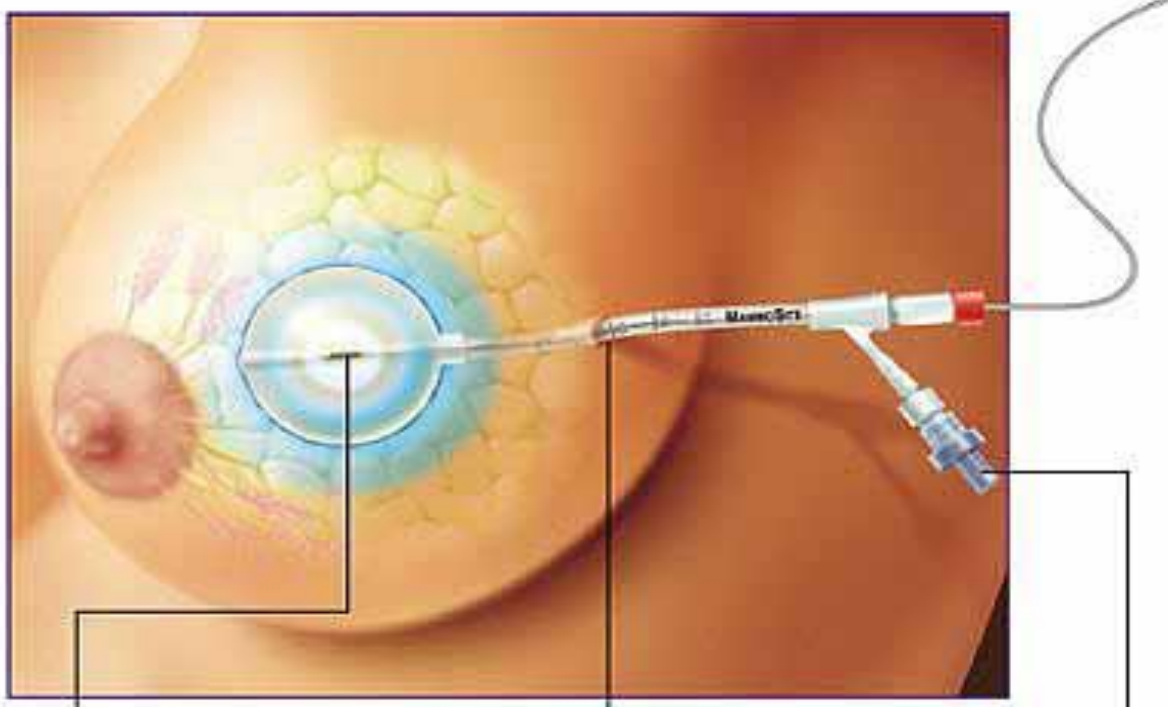
- Where possible, allows delivery of higher doses of radiation to more-specific areas
- Typically causes fewer side effects than does external beam radiation, and the overall treatment time is usually shorter

Used to treat brain, breast, lung, pancreas, prostate, esophagus, cervix,….

Where do balloons come in?

Jefferson Lab

Example: Brachytherapy for Partial Breast Irradiation



An ^{192}Ir source (connected to HDR afterloader, above) is positioned within the center of the MammoSite balloon to deliver a highly conformal dose to the area immediately surrounding the resected tumor

- A trocar is used to create a pathway to the lumpectomy cavity for insertion of the catheter
- The MammoSite RTS is inflated with saline to allow the surrounding tissue to conform to the balloon

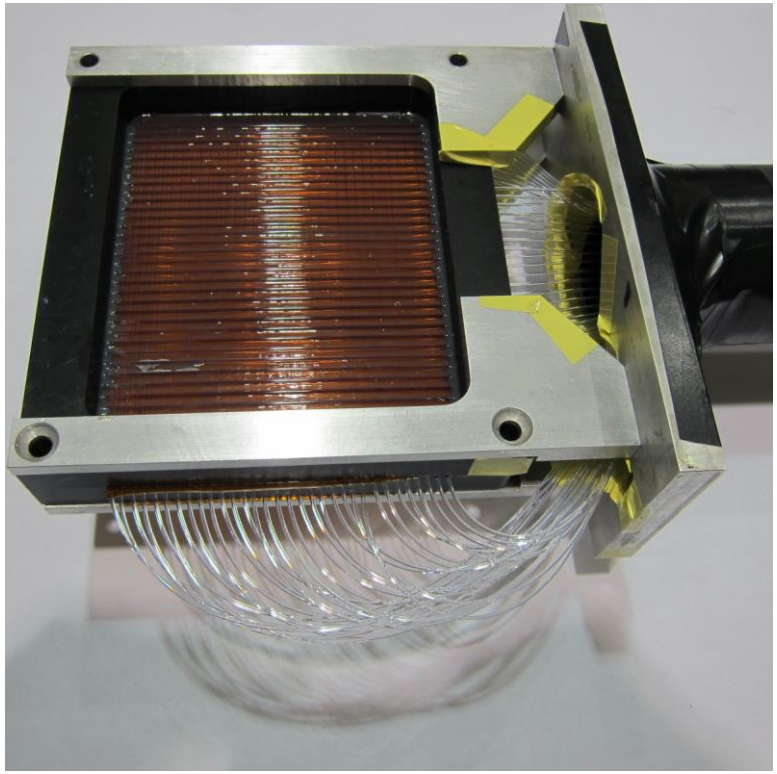
- Radiation is delivered via a high-dose rate (HDR) remote afterloader under precise computer control
- The MammoSite RTS is compatible with Nucletron, Varian, and GammaMed® HDR afterloader equipment

- Shorter course of treatment
- Reduced local recurrence rates (0-3%)

"Active Catheter" Development at Hampton University

- *NO real time dose distribution feedback!*
  - HDR Brachytherapy dose calculations are based on computer simulations and *in-vitro* measurements. It is difficult to set a tolerance level because according to AAPM's TG56: *"no practical and validated dose measurement technology is available to the hospital physicist".*
- *Can be large doses*
- *In-vivo dose measurements would allow for real time evaluation of dose delivered to patient.*
  - Increase patient safety since the detector may be used for dose-at-a-point confirmation or to monitor dose absorbed by critical organs.

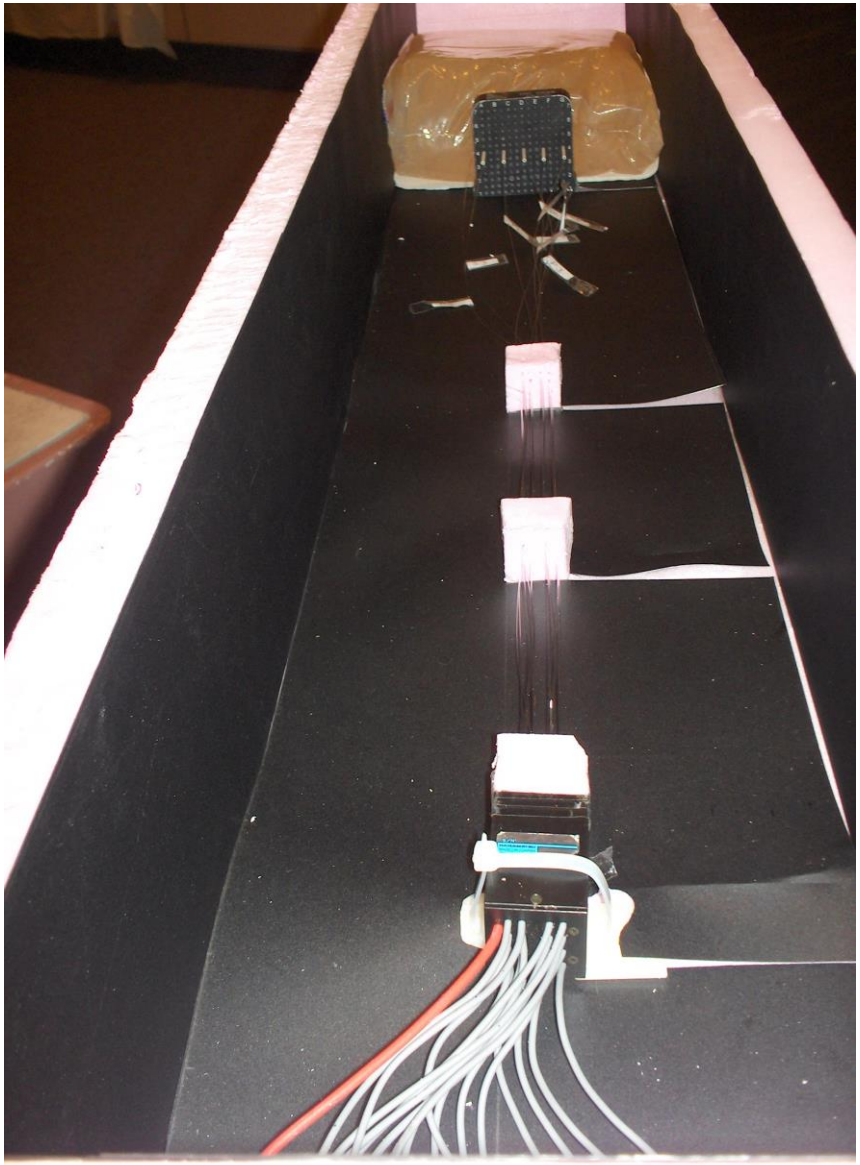
- ***Idea: What about scintillating fibers (used in nuclear physics) placed INSIDE the catheters?***



Scintillating fiber array for APEX experiment at Jefferson Lab

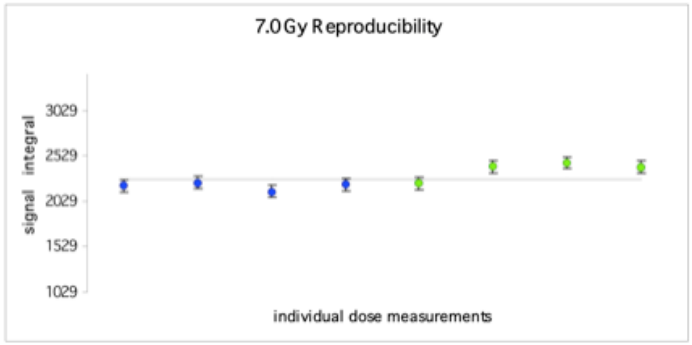
Scintillating Fiber Dosimetry

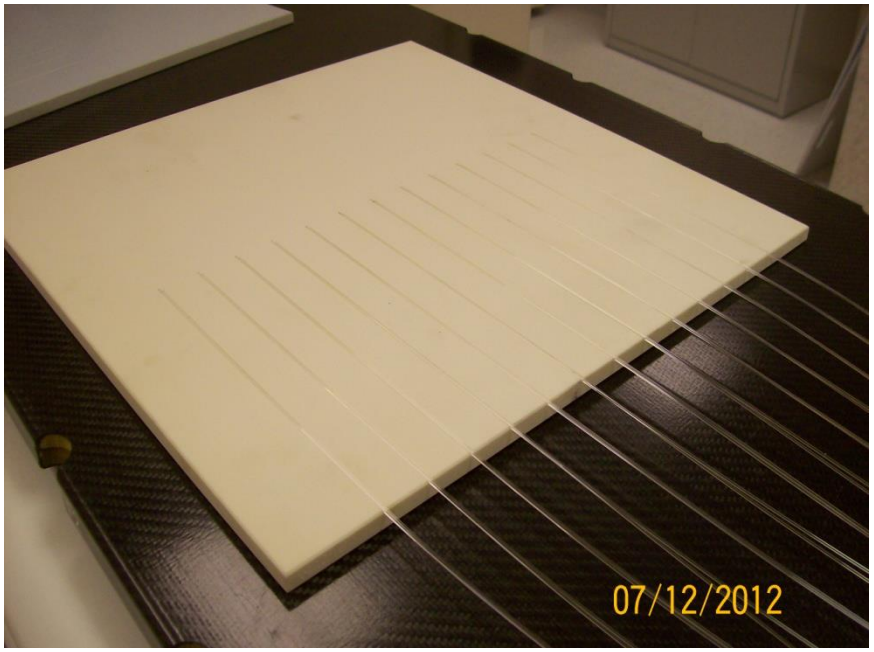
- Hair-like, bendable, radiation sensitive detectors
- Produce light output proportional to dose delivered
- Couple to straightforward electronics

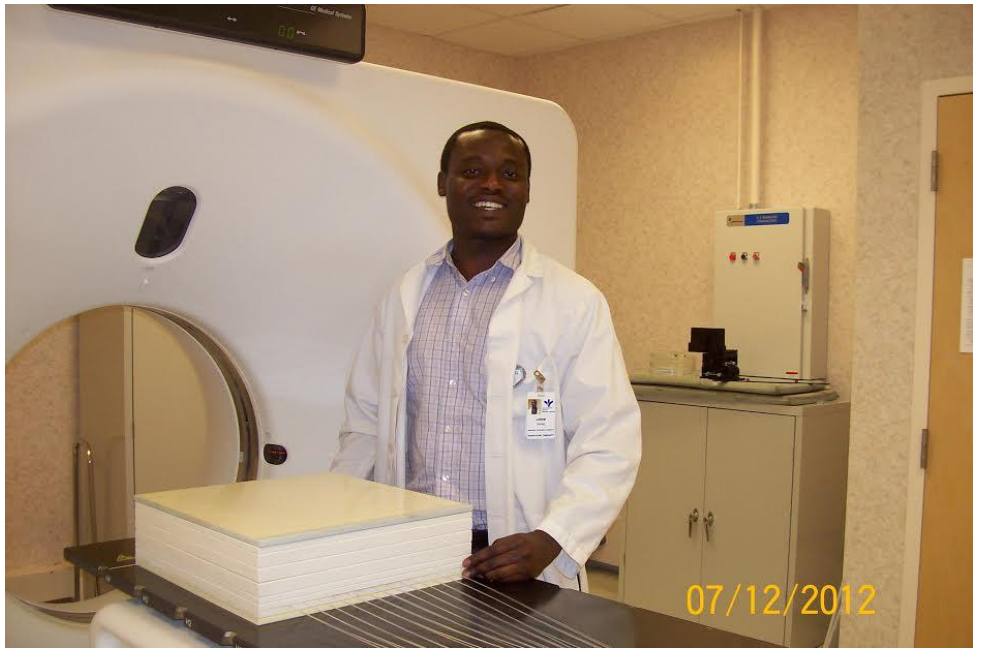


First test set-up: used gelatin mold and brachytherapy surgery metallic template to hold the fibers in place, coupled to Hamamatsu PSPMT

- Students (at that time) Lawrence Tynes, Melissa Barruzza, Carlos Velasco
- HDR unit at Bon Secours DePaul Hospital in Norfolk, VA
- Dose reproducibility studies (also with water phantom and MOSFETs) looked positive….

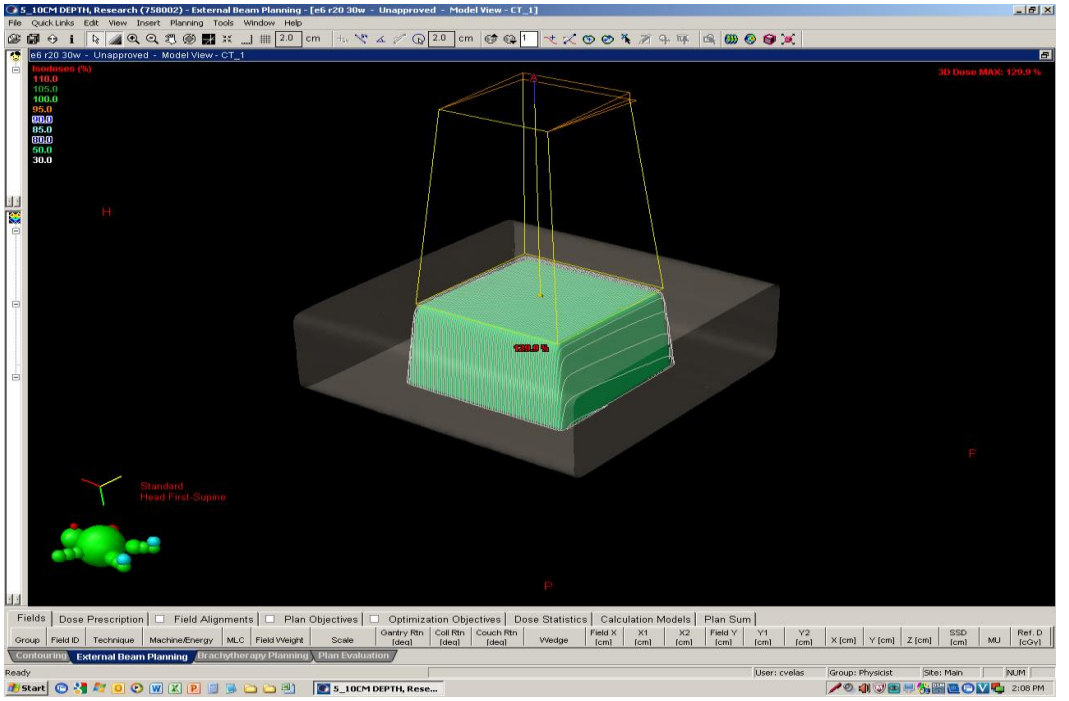






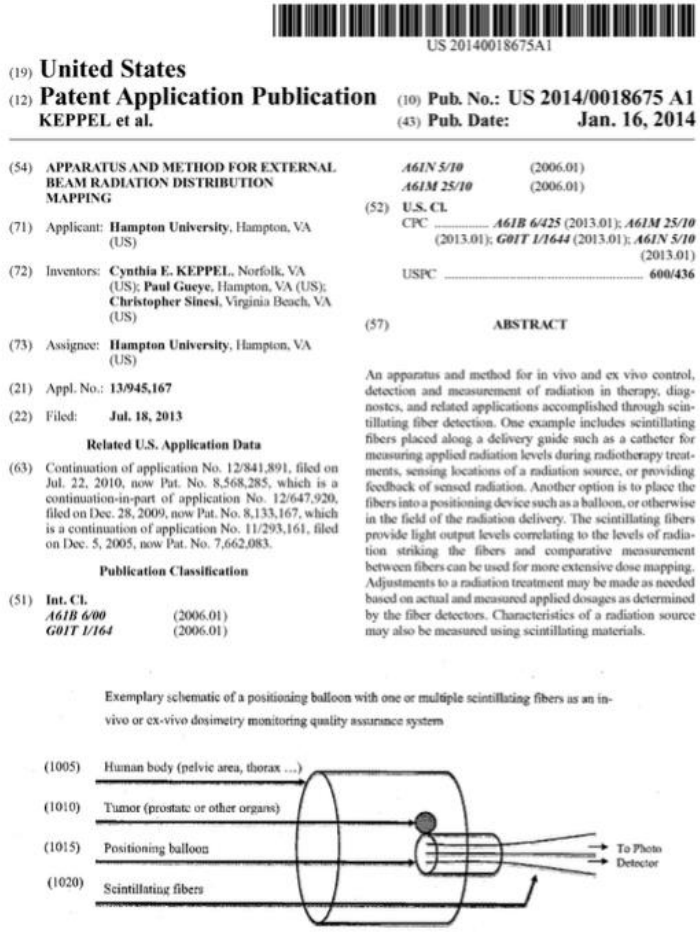
Continued testing…

- Instrumented a solid water phantom
- Compared to full treatment plan (as well as GEANT4)
- External beam irradiation
- Determined calibration procedure
- Thesis for (then) doctoral student John Okine



Fast forward…

- We patented the technology….



US 20140018675A1

(19) **United States**

(12) **Patent Application Publication**

KEPPEL et al.

(10) **Pub. No.: US 2014/0018675 A1**

(43) **Pub. Date: Jan. 16, 2014**

(54) **APPARATUS AND METHOD FOR EXTERNAL BEAM RADIATION DISTRIBUTION MAPPING**

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(73) Assignee: **Hampton University**, Hampton, VA (US)

(21) Appl. No.: **13/945,167**

(22) Filed: **Jul. 18, 2013**

Related U.S. Application Data

(63) Continuation of application No. 12/841,891, filed on Jul. 22, 2010, now Pat. No. 8,568,285, which is a continuation-in-part of application No. 12/647,920, filed on Dec. 28, 2009, now Pat. No. 8,133,167, which is a continuation of application No. 11/293,161, filed on Dec. 5, 2005, now Pat. No. 7,662,083.

Publication Classification

(51) **Int. Cl.**

A61B 6/00 (2006.01)

G01T 1/164 (2006.01)

A61N 5/10 (2006.01)

A61M 25/10 (2006.01)

(52) **U.S. Cl.**

CPC ***A61B 6/425*** (2013.01); ***A61M 25/10*** (2013.01); ***G01T 1/1644*** (2013.01); ***A61N 5/10*** (2013.01)

USPC **600/436**

(57) **ABSTRACT**

An apparatus and method for in vivo and ex vivo control, detection and measurement of radiation in therapy, diagnostics, and related applications accomplished through scintillating fiber detection. One example includes scintillating fibers placed along a delivery guide such as a catheter for measuring applied radiation levels during radiotherapy treatments, sensing locations of a radiation source, or providing feedback of sensed radiation. Another option is to place the fibers into a positioning device such as a balloon, or otherwise in the field of the radiation delivery. The scintillating fibers provide light output levels correlating to the levels of radiation striking the fibers and comparative measurement between fibers can be used for more extensive dose mapping. Adjustments to a radiation treatment may be made as needed based on actual and measured applied dosages as determined by the fiber detectors. Characteristics of a radiation source may also be measured using scintillating materials.

Exemplary schematic of a positioning balloon with one or multiple scintillating fibers as an in-vivo or ex-vivo dosimetry monitoring quality assurance system

Small note: Dosimetric approach also suggested for use in brachytherapy catheters (non-balloon type)

Jefferson Lab

...and it was licensed

List of OARtrac® Patents from Radiadyne web page:

US 8603129 B2
US 8885986 B2
US 8953912 B2
*US 7662083
*US 8133167 B2
*US 20140018675

*Hampton University patents developed by HU/JLab Center for Advanced Medical Instrumentation – *licensed to Radiadyne*

...and Radiadyne put in a lot of time, effort, investment, cleverness, dedication - and beyond - to bring it to market...

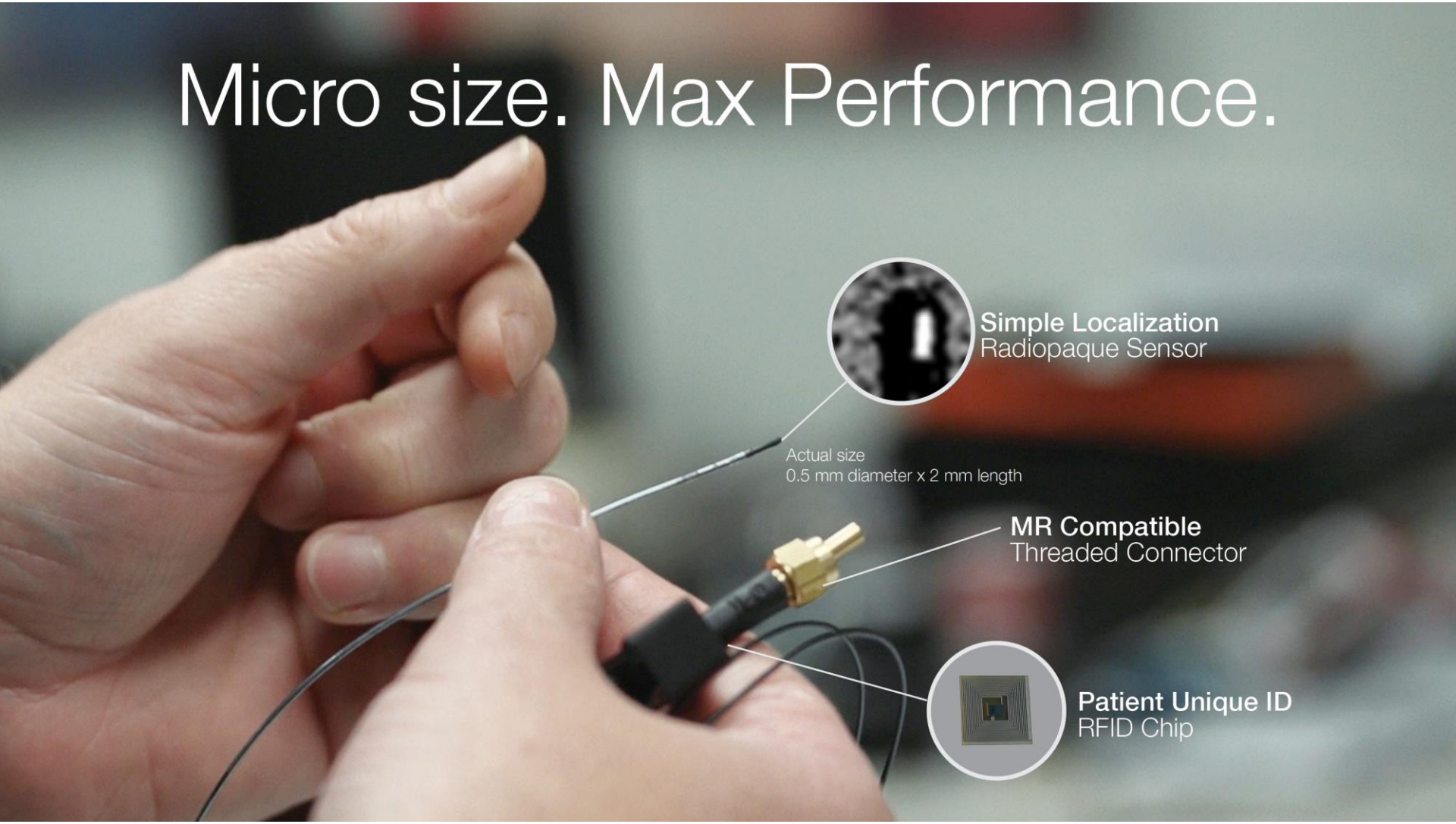
RADIADYNE®

OARtrac® plus


Transformation
in Dosimetry Monitoring

After eight years and millions of dollars invested in research and development, OARtrac® Plus is the first of its kind radiation dose monitoring platform providing gold standard accuracy without correction factors, real-time pinpoint measurement, and dedicated intracavitary delivery devices to measure where it counts.

OARtrac® Plus monitors multiple cancer treatment modalities within the same treatment center, as well as reduces overall treatment costs related to routine patient dose monitoring through a reusable dosimeter.


Micro size. Max Performance.
Simple Localization
Radiopaque Sensor
Actual size
0.5 mm diameter x 2 mm length
MR Compatible
Threaded Connector
Patient Unique ID
RFID Chip

microPSD

Plastic Scintillating Detector

Water Equivalent

PSD Sensors are manufactured using water equivalent materials and will not perturb the energy deposition process.

FDA Cleared For Reusability

Up to five times with no additional correction factors for cost effective clinical adoption.

Consistent Repeatability

±1%

Excellent precision and repeatable data without degradation of dose response or additional correction factors.

Excellent Accuracy

±2.5%

Highly accurate pinpoint measurement in real-time, and exhibits excellent energy independence.


Dose Monitoring at Light Speed
The scintillation light created from radiation interaction is emitted within nanoseconds down the fiber optic cable to the clinical detector unit for real-time measurement.

Clinical Detector Unit
Millisecond Processing

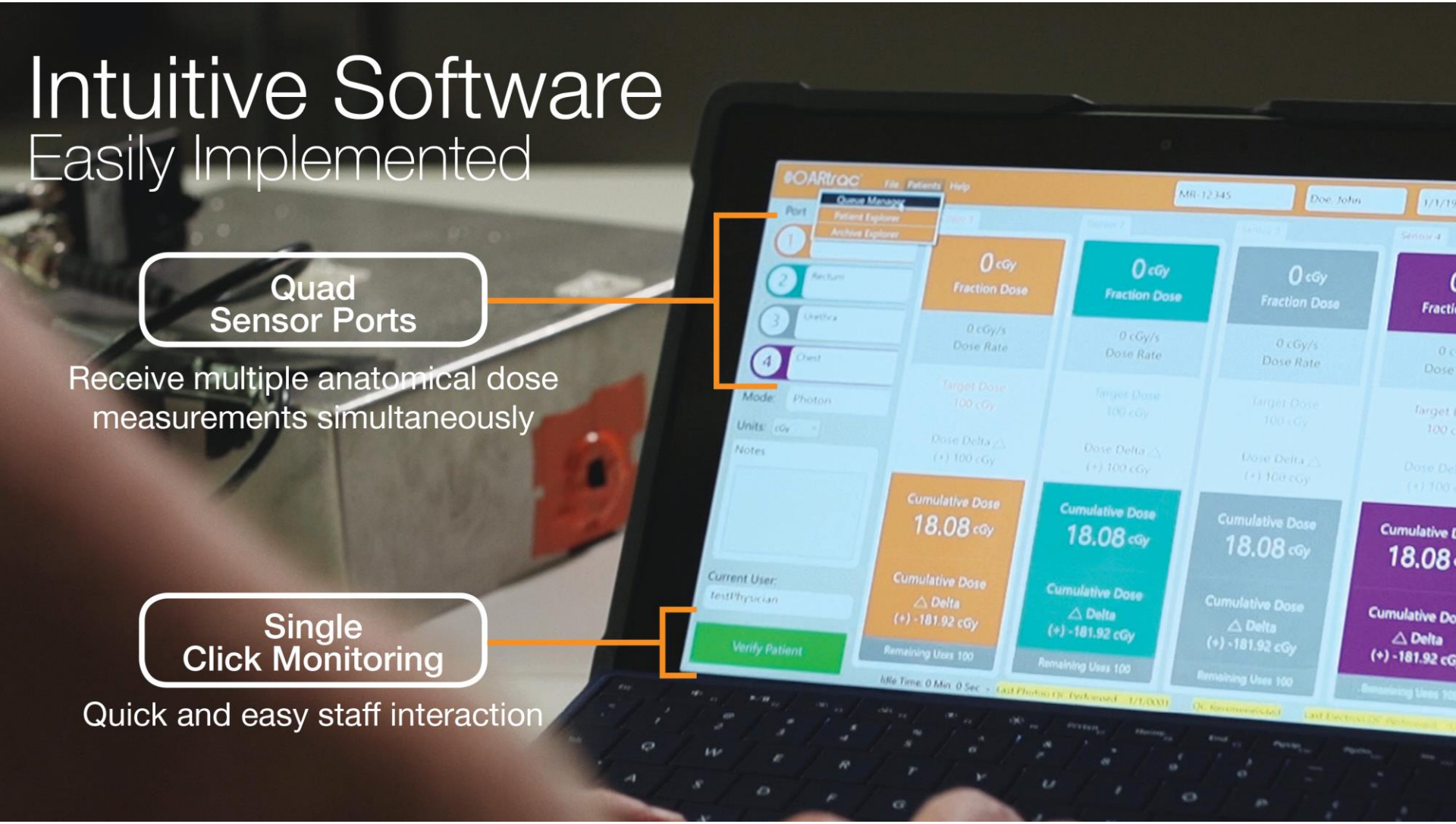
Low Energy Dependence
Monitor dose from a low to high energy range (0.2Mev to 20Mev) with no correction factors.

Four Sensor Ports
Measure up to four anatomical readings simultaneously with color coded microPSD sensors.

Real-Time Dose Measurement
Sub-second processing speed providing valuable data for adaptive radiotherapy.

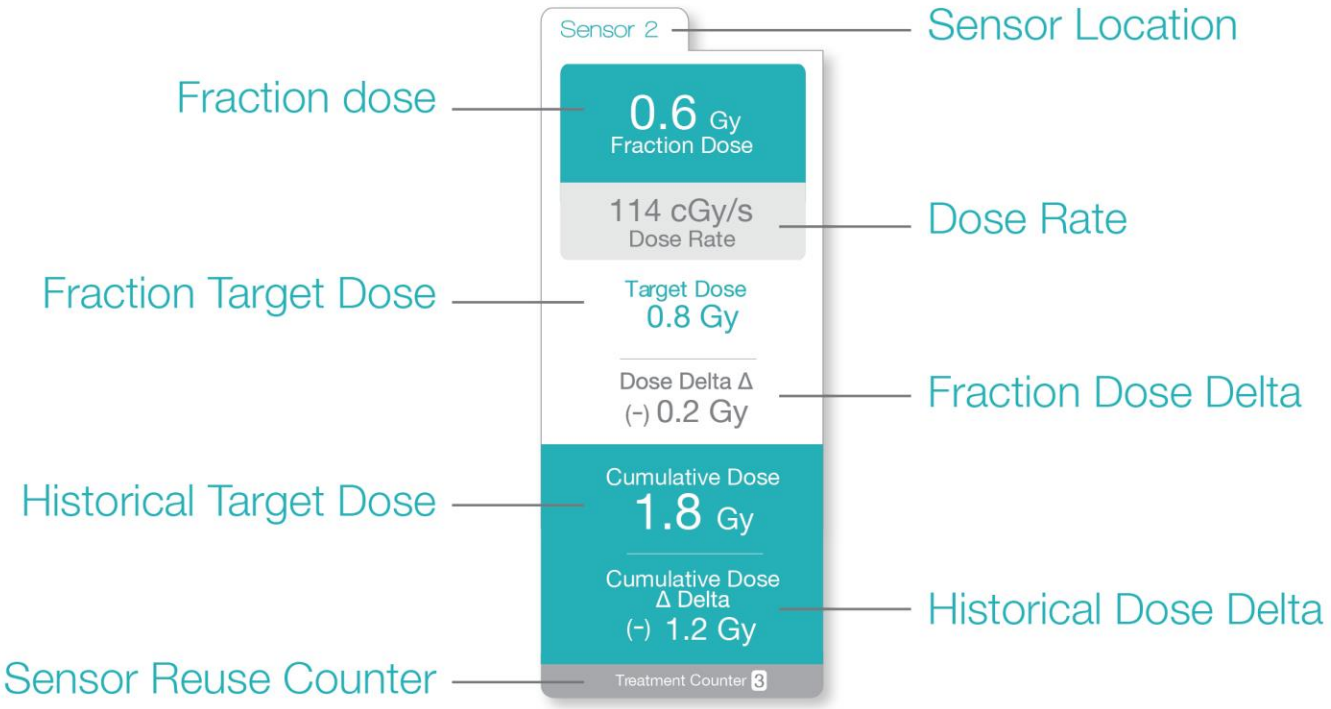
Monitors Multiple Modalities
Universally measures dose for SBRT, IMRT, Cyberknife, Electron*, and HDR Brachytherapy treatment modalities.

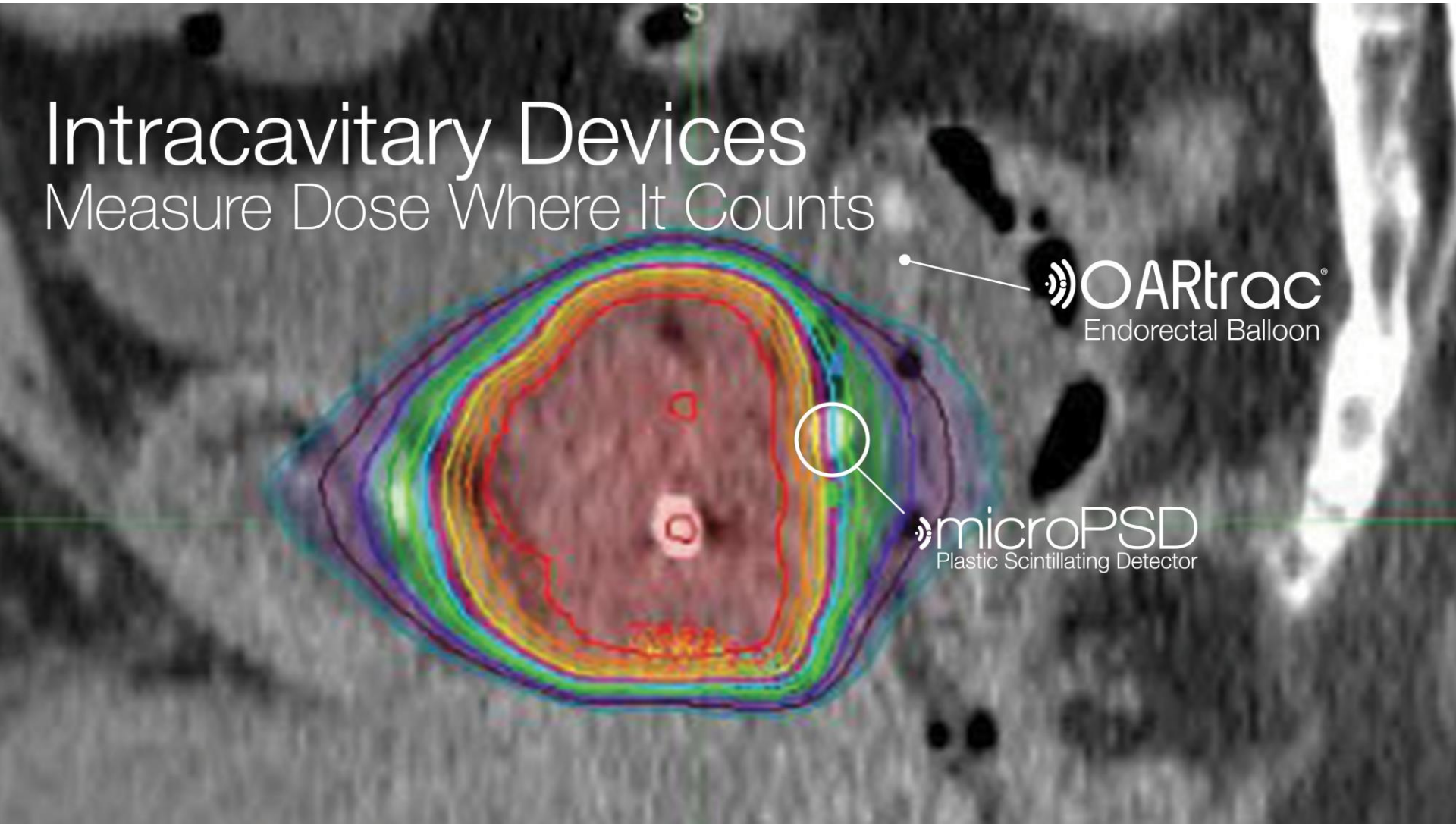
*pending FDA clearance


Intuitive Software
Easily Implemented
Quad
Sensor Ports
Receive multiple anatomical dose measurements simultaneously
Single
Click Monitoring
Quick and easy staff interaction
OARtrac
Fraction Dose
Cumulative Dose
18.08 cGy
Verify Patient

Comprehensive Data

Captures Intrafractional & Historical Dose




Intracavitary Devices
Measure Dose Where It Counts
OARtrac®
Endorectal Balloon
microPSD
Plastic Scintillating Detector

Universal Capabilities

Specific Anatomical Monitoring

GI

Endorectal Balloon
Stabilizes the Prostate and provides real-time dose measurement at the rectal prostatic interface.

Skin

Skin With Bolus
Measures skin dose for Photon, Electron* and HDR Brachytherapy, as well as entrance dose.

GU

Urinary Catheter*
Sterile MR microPSD compatible with commercially available urinary catheters for point dose measurements.

GYN

Vaginal Cylinder & Vaginal Balloon Packing*
Provides real-time dose information for the organs at risk during GYN treatments.

Future Applications - multiple delivery devices in final stages of development for head & neck and in situ applications.*

*pending FDA clearance


Plug and Play
Precalibrated sensors offer easy routine clinical dose monitoring for the Therapist, Physicist, and Radiation Oncologist.

How It Works

Simple Workflow For Routine Use

Radiation delivered

Interacts with the microPSD

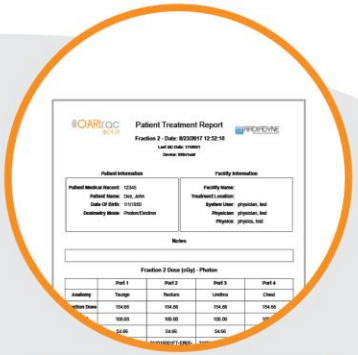
Creates visible light

Travels down optical fiber

Measured & digitized

Translated into dose

Dose measurement output



EMR Patient Report


Significant Clinical Advantages Over
OSLDs, TLDs, and MOSFETs
The OARtrac® Plus Platform Offers Real-Time In-Vivo
Dose Data For True Adaptive Radiotherapy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Simple. Accurate. Real-Time.
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Thank you!

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