# Brachytherapy with Miniature Electronic X-ray Sources

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# DISCLOSURE

**Dr. Rivard serves as a consultant and Dr. DeWerd receives research support from Xoft, Inc.**

# HISTORY

Electronic brachytherapy (eBx) applies interstitial irradiation without radionuclides

A miniature x-ray tube is commonly employed

eBx conceived in the 1980s by Alan Sliski of PhotoElectron Corp. in collaboration with MIT

Dosimetric properties and source characteristics first published in 1993 (Biggs *et al*., Gall *et al*., Smith *et al.*) in *Medical Physics*

~ 10 other companies pursued eBx since then

# RATIONALE

| Bx Source | Advantages | Disadvantages |
|---|---|---|
| radionuclide | Well established therapeutic use<br>Well established calibration procedures<br>Fixed photon spectrum and half-life<br>High specific activity, small size | Fixed dosimetry properties<br>Radioactive waste concerns<br>Regular source shipments due to decay |
| electronic | User-adjustable dose rate (on/off)<br>User-adjustable dosimetric properties<br>Lessened radiological exposure to staff | Unproven clinical application<br>No NIST calibration protocol<br>Output variability amongst sources<br>Typically larger in size |

No statements may be made at this time regarding cost differences or clinical results

# VENDOR SCOPE

1. Advanced X-ray Technologies Inc.
   Birmingham, MI

2. Carl Zeiss Ltd.
   Oberkochen, Germany

3. Xoft Inc.
   Fremont, CA

# Advanced X-ray Technologies

Use of a primary and secondary targeting system with substantial polar and azimuthal anisotropy

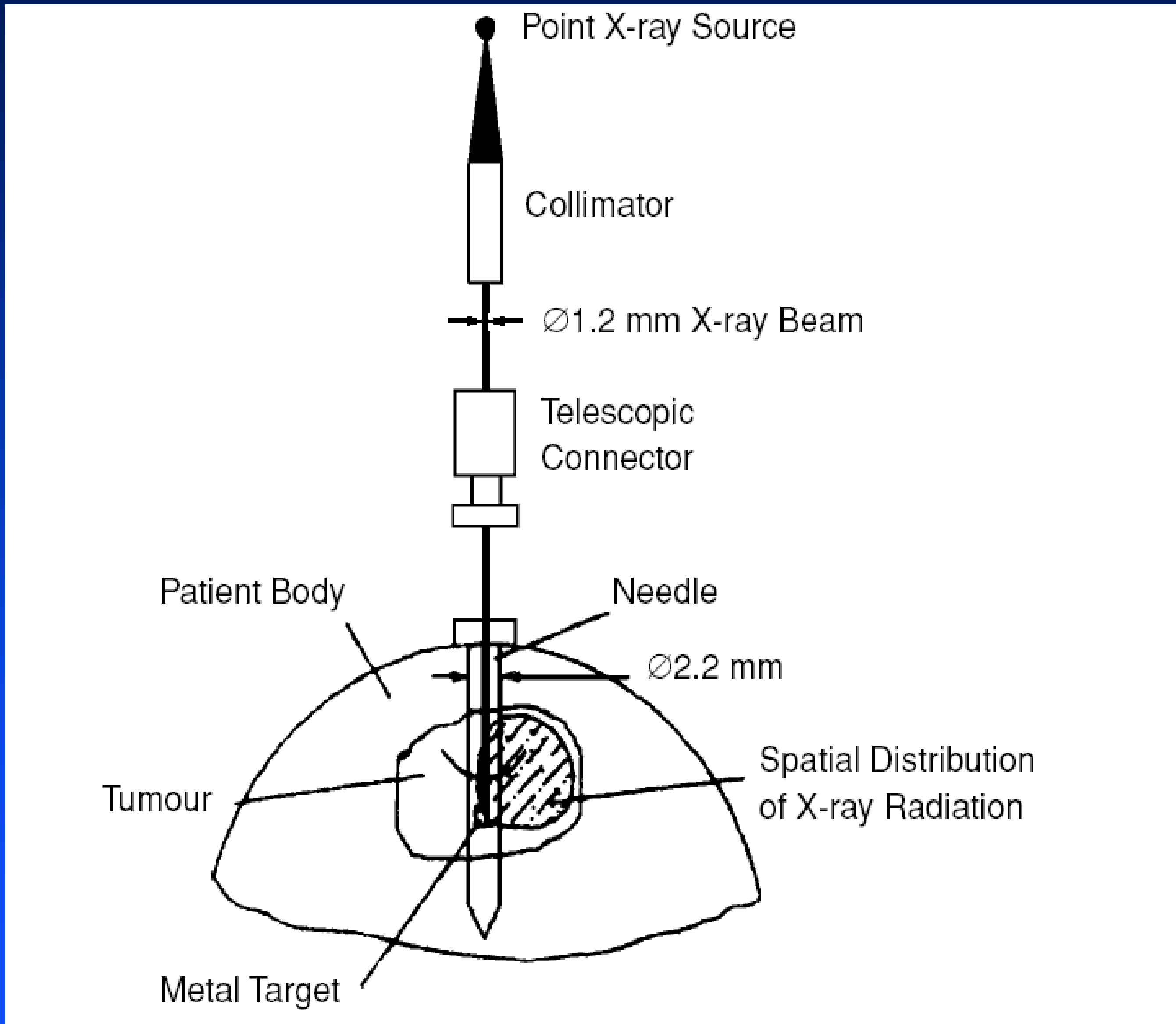
1.5 kW, 90 kV x-rays from primary target are directed down a 2.2 mm OD shaft to impinge *in vivo* secondary target

Variety of primary and secondary target materials

Best penetration with W:Nd target combo for $g(0.5) \sim 1$ and $g(3) = 0.9$; max dose rate ~ 0.6 Gy/h

System not yet FDA approved

# Advanced X-ray Technologies

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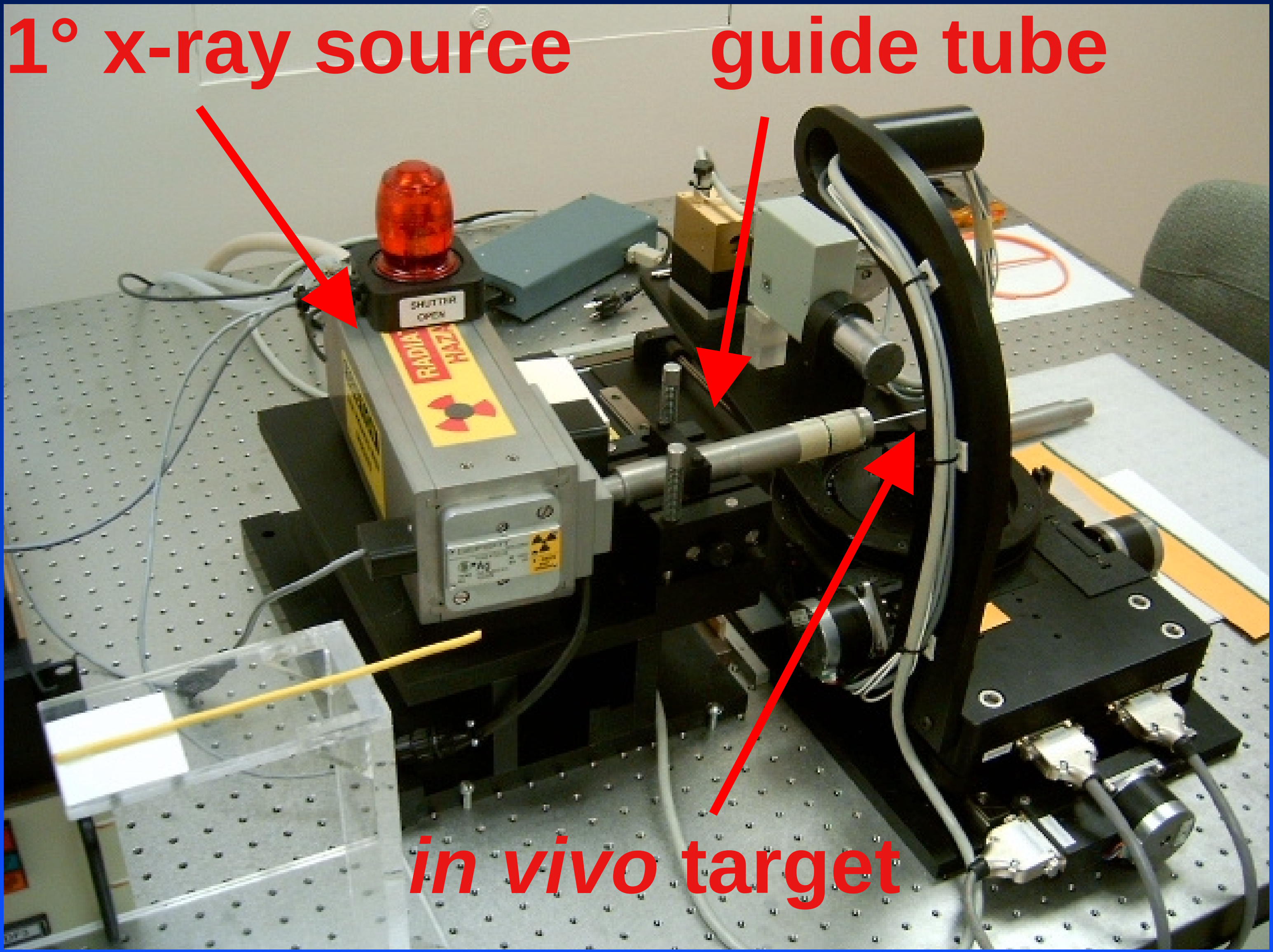
# Advanced X-ray Technologies

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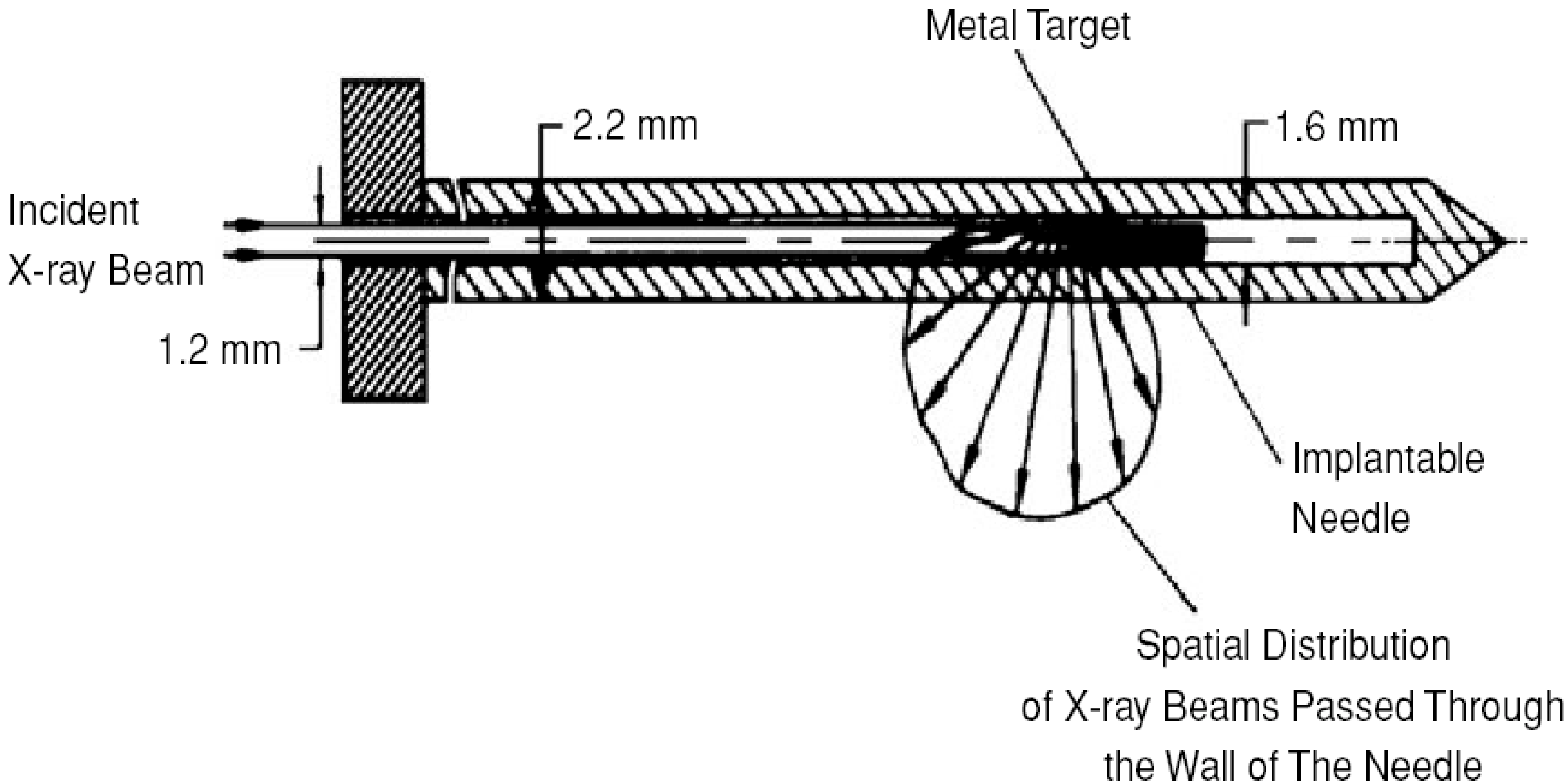
# Advanced X-ray Technologies

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# Carl Zeiss Ltd.

PhotoElectron Corp. sold technology to Zeiss Ltd.

Over 300 IORT patients (primarily Europe) treated with INTRABEAM™ Photon Radiosurgery System

Intracranial lesions and breast post-op similar to Proxima (now Cytyc) GliaSite and MammoSite

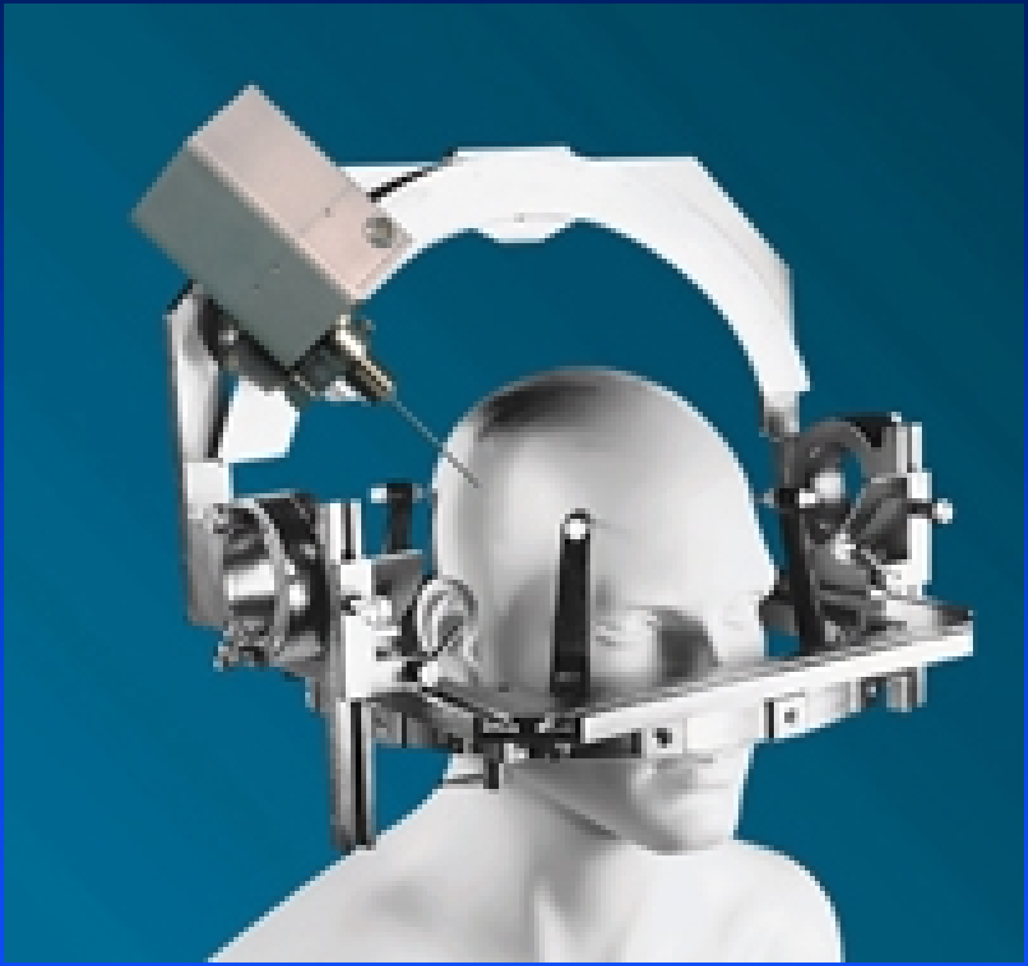
50 kV $e^-$ @ 40 μA on Au target, 3.2 mm Ø source

780, 168, 60, and 30 Gy/h @ 1, 2, 3, and 4 cm

$g(2) = 0.9$ and $g(3) = 0.7$

# Carl Zeiss Ltd.

# Carl Zeiss Ltd.



Intracranial and post-operative breast conserving surgical IORT

# Carl Zeiss Ltd.

# Xoft Inc.

Manufacturer initially pursued IVBT, now seeks to provide HDR $^{192}Ir$ alternative for diverse lesions

50 kV $e^{-}$ @ 300 μA on Au target, 5 mm Ø source

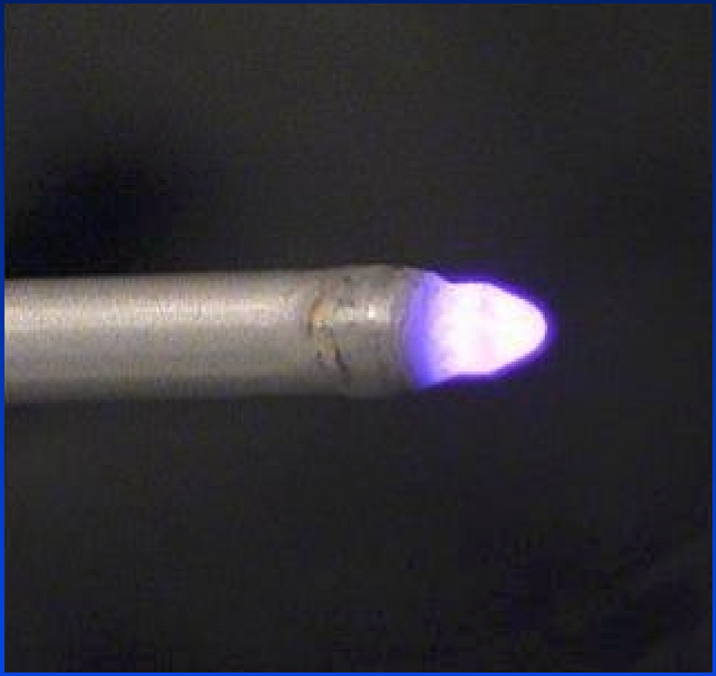
900, 135, 50, and 11 Gy/h @ 1, 2, 3, and 5 cm

$g(2) = 0.6$, $g(3) = 0.5$, $g(5) = 0.3$, and $g(10) = 0.1$

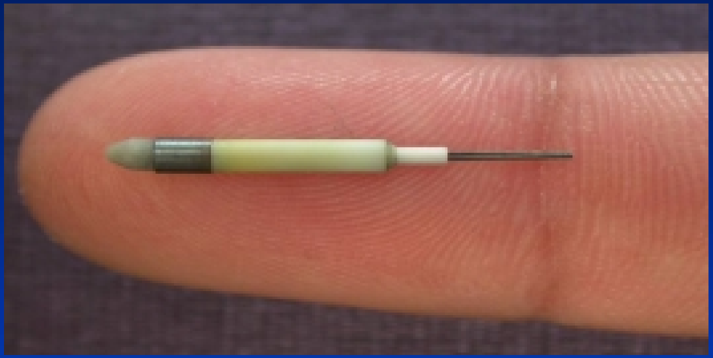
Similar dosimetric properties to a HDR $^{125}I$ source

System not yet FDA approved for APBI

# Xoft Inc.



Light emission from e⁻ and x-ray interactions with anode



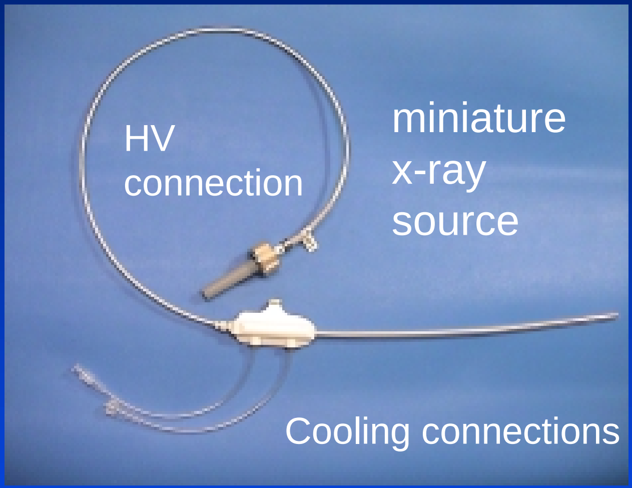
X-ray tube size

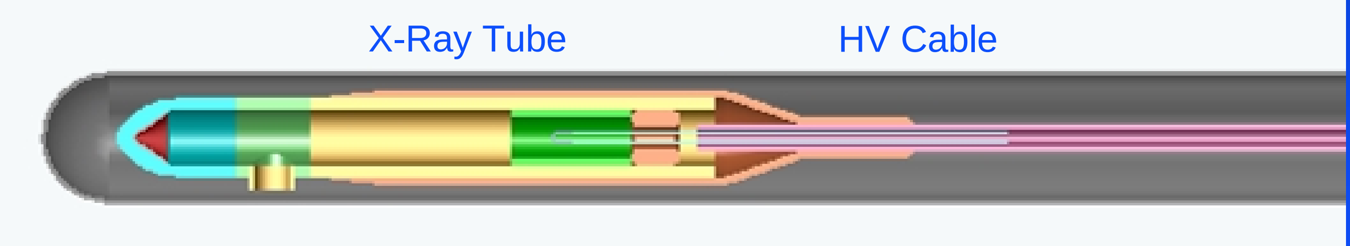
X-ray source in cooling catheter

# Xoft Inc.

Miniature x-ray source inserted into a flexible cooling catheter

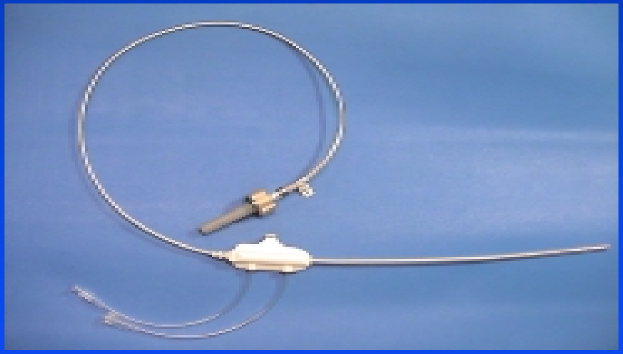
- High vacuum x-ray tube technology
- 50 kV max. operating potential
- Water cooled
- Fully disposable device




X-ray source tip detail

# Xoft Inc.



APBI system components

# Xoft Inc.

UW Attix FAC measurements of source strenggth

Applying all corrections, air kerma strength can be determined and transferred to a well ionization chamber such as HDR-1000 Plus

The values to about 2% precision are:

40 kV: $4.263 \times 10^2$ Gy-m$^2$/C

45 kV: $3.234 \times 10^2$ Gy-m$^2$/C

50 kV: $2.653 \times 10^2$ Gy-m$^2$/C

This values are not yet *in-vacuo*

# Clinical Implementation of eBx

No NRC radioactive materials license needed

Consider AAPM Task Group Reports and Guidance

– TG-43 Brachytherapy Dosimetry Formalism
– TG-56 Code of Practice for Brachytherapy
– TG-59 High Dose Rate Tx Delivery

Comparisons of measured and calculated dose distributions, development of consensus dataset as established for radionuclide-based Bx

Need development of eBx NIST calibration standard for consistent clinical implementation

# Summary

eBx sources can have similar dose distributions to LDR $^{125}I$ and similar dose rates to HDR $^{192}Ir$

eBx sources can have many attractive features like: on-off, adjustable output, variable energy, and independence from a radioactive materials license

With further development, eBx source can potentially replace radionuclide-based brachytherapy like linear accelerators replaced $^{60}Co$ in the 1900s