Electronics X-ray Sources for Brachytherapy

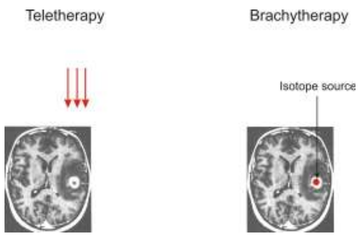
Mieczysław Słapa, Marek Traczyk, Marcin Talejko,
Krzysztof Wincel, Barbara Zaręba

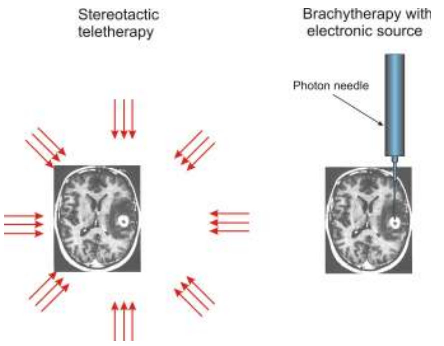
The Andrzej Sołtan Institute for Nuclear Studies
Department of Physics Applications

Cancer treatment is a compound process – the patient should be (as far as possible) subsequently treated according to the following three different medical procedures: surgery, radiotherapy, chemotherapy.

The aim of radiotherapy is to destroy all cancer cell micro-lesions that might be left over after a surgery resection of a tumor, or – in cases when no tumor surgery is possible – to destroy the entire tumor or else at least to slow down its growth. To this end some ionizing radiation is used.

Radiotherapy can be divided into teletherapy (irradiation of the object with external rays) and brachytherapy (source of radiation is located inside of irradiated object).

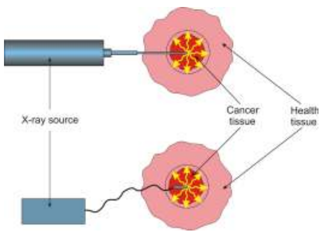




Topics to be covered hereafter:

- X-ray tube as a radiation source for brachytherapy
- features of the currently used X-ray tubes for brachytherapy
- current status and trends in medical applications
- development works on electronic radiation sources in IPJ.

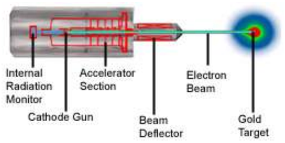
Electronics Brachytherapy Sources - EBS



To be useful for brachytherapy, an X-ray tube construction must enable to enter its target (anode) inside the to-be-irradiated object. Besides, it must emit radiation isotropically into the whole 4 pi solid angle. Currently two approaches are followed:

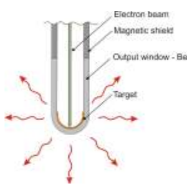
- X-ray tube with needle-like anode,
- miniature X-ray tubes that might be totally put inside the to-be-irradiated tumor.

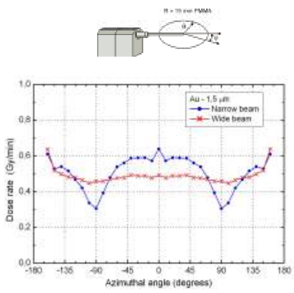
Photon Radiosurgery System - PRS400
Photoelectron Corporation, Carl Zeiss



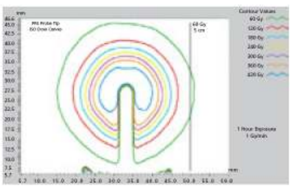
Miniature X-ray Source:
- Energy (max): 50 kV, 40 µA
- Weight: 1.57 kg (3.45 lbs)
- Size: 17.5 x 11 x 7 cm
- Probe dimensions: 3.2 mm diameter, 10 cm long,
- Dose rate: 2.5 Gy/min (at 1 cm depth in water)

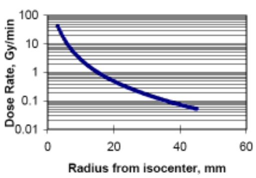
Electronics Brachytherapy Sources - EBS



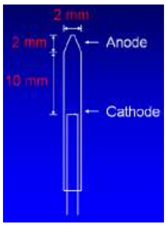


Photon Radiosurgery System - PRS400





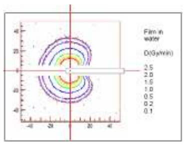
Xoft Axxent electronic brachytherapy source

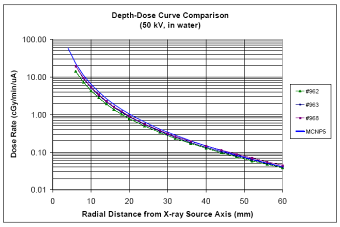


Miniature X-ray source inserted into a flexible cooling catheter.

- High vacuum x-ray tube technology.
- 50 kV operating potential, 300 μA current.
- Output: ~1 Gy/minute at 3 cm depth in wate.
- Water-cooled.
- Fully disposable device.

Xoft Axxent electronic brachytherapy source



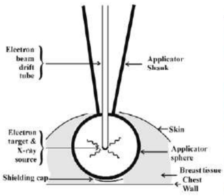


Parameter	PRS 400	Xoft Axxent
Anode bias	50 kV	50 kV
Anode current	40 μA	300 μA
Probe dimensions	10 cm long rigid pipe, ext. dia 3.2 mm	20 x 5 mm capsule at the end of a flexible cable
Dissipated power	2 W	15 W
Cooling	Natural	Water
Lifetime	Several thousand hours	A few hours
Applicator dia	1.5…5 cm	3…7 cm
Applicator shape	Sphere	Sphere, ellipsoid

Current status and trends in medical applications of EBS systems

1. An early stage of EBS technology development.
2. Intra-Operative Radiation Therapy (IORT): a supporting radiotherapy - boost.
3. Accelerated Partial Breast Irradiation (APBI): a complete radiotherapy
   - single day radiotherapy (PRS400),
   - HDR radiotherapy (5 days, Xoft). In 2006 Xoft's Axxent Electronic Brachytherapy System has received FDA clearance to treat breast cancers.
4. EBS development prognosess.

IORT boost using the PRS400 device



Schematic diagram of the applicator

The pliable breast tissue- wraps around the source

APBI using the Xoft's Axxent

EBS development perspectives

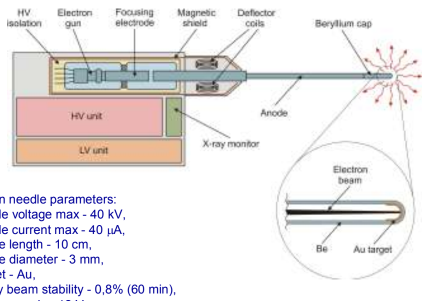
1. In the nearest future EBS sources may become an important tool used in the conserving method of breast cancer treatment, both as a boost source within the IORT procedure, and within the APBI procedure.
2. It may be safely assumed that some new EBS constructions for brachytherapy of other body organs will be developed in the years to come. In particular demand may appear for sources specialized for brachytherapy of such organs, which do not render themselves to teletherapy (e.g. tumors located too close to some body organs particularly sensitive for ionizing radiation).
3. EBS sources may to a great extent restrict use of radioisotopes in the IORT and/or APBI procedures, or even completely eliminate them from clinical practice.

Comparison of EBS/radioisotope sources

- Energy and intensity of radiation generated by electronic sources may be regulated by changing the X-ray tube bias voltage and current. That simple way the irradiation procedure may be easily optimized.
- At any moment an electronic source may be turned on/off, which allows to significantly limit exposition of the medical team to radiation.
- Significantly lower energy of X-rays as compared to the Ir-192 isotope source makes possible to use EBS sources practically in any operation room.
- EBS sources need neither expensive catering installations nor specialized radioisotope storage rooms.

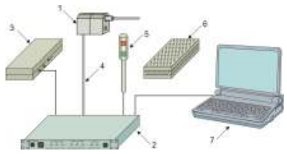
Polish Photon Needle

for brachytherapy brain tumor



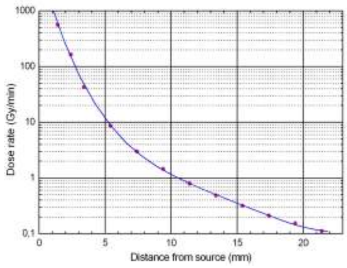
Photon needle parameters:
- anode voltage max - 40 kV,
- anode current max - 40 μA,
- probe length - 10 cm,
- probe diameter - 3 mm,
- target - Au,
- X-ray beam stability - 0,8% (60 min),
- voltage suply - 12 V.

Polish Photon Needle



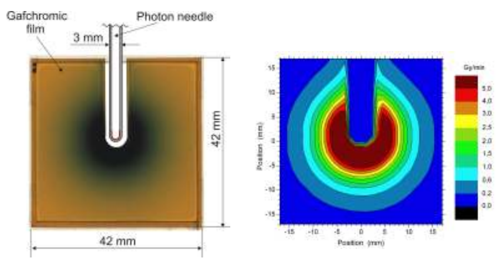
Components of the PIF system include:
- the photon needle miniature X-ray generator (1),
- the generator power supply and controller (2),
- test chamber (3),
- 6 m long cable linking the generator and its power supply/controller unit (4),
- X-ray generator state indicator (5),
- chamber for gas sterilization of the generator (6),
- laptop with the PIF-controlling software (7).

Polish Photon Needle



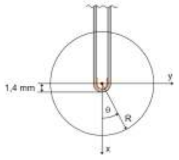
Radial distribution of dose-rates in water (40 kV, 40 μA)

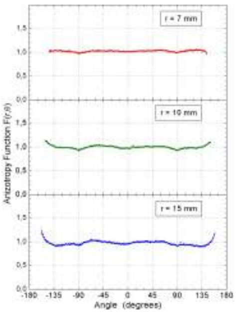
Polish Photon Needle



Measurement 2-D dose distribution in water
U_a = 40 kV, I_a = 40 μ A, time = 20 min.

Polish Photon Needle





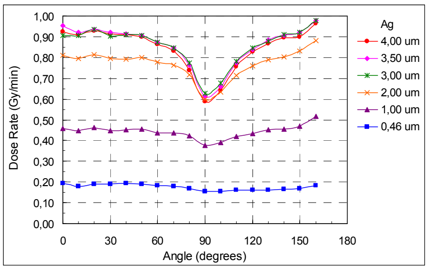
Anizotropy function

New EBS for Intra-Operative Radiation Therapy

Our team has started development of a new electronic source for brachytherapy to be applied within the conserving method of treating breast cancers.

Currently the works are focused on Monte-Carlo simulations of energy spectra, dose-rate spatial distributions, radiation field isotropy etc. as a function of X-ray tube target material and construction, electron beam geometry and anode bias voltage/current. Increase of the mean X-ray energy (in order to lengthen the effective treatment range) and decrease of the radiation field anisotropy (as compared to parameters obtained in the *photon-needle* solution) are sought.

We expect that the project will be supported within the framework of the Innovative Economy Operational Program IEOP 2007-2013 (European Union structural funds).



Calculated angular distribution of X-ray dose rate in PMMA.
Non-swept electron beam. U_a = 50 kV, I_a = 20 μA