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 attempt 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).
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 4π 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.

### 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.
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)

Photon Radiosurgery System - PRS400
Photoelectron Corporation, Carl Zeiss

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, 200 µA current.
- Output: ~1 Gy/minute at 3 cm depth in wate.
- Water-cooled.
- Fully disposable device.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PRES 605</th>
<th>Xoft Axxent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode bias</td>
<td>50 kV</td>
<td>50 kV</td>
</tr>
<tr>
<td>Anode current</td>
<td>200 µA</td>
<td>200 µA</td>
</tr>
<tr>
<td>Probe dimensions</td>
<td>10 cm long rigid pipe, ext. dia 3.2 mm</td>
<td>20 x 5 mm capsule at the end of a flexible cable</td>
</tr>
<tr>
<td>Dissipated power</td>
<td>2 W</td>
<td>2 W</td>
</tr>
<tr>
<td>Cooling</td>
<td>Natural</td>
<td>Water</td>
</tr>
<tr>
<td>Lifetime</td>
<td>Several thousand hours</td>
<td>A few hours</td>
</tr>
<tr>
<td>Applicator dia</td>
<td>1.5 - 5 cm</td>
<td>3 - 7 cm</td>
</tr>
<tr>
<td>Applicator shape</td>
<td>Sphere</td>
<td>Sphere, ellipsoid</td>
</tr>
</tbody>
</table>
Current status and trends in medical applications of EBS systems

1. An early stage of EBS technology development.
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 progresses.

IORT boost using the PRS400 device

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 I-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

- anode voltage max: 40 kV,
- anode current max: 40 µA,
- probe length: 10 cm,
- probe diameter: 3 mm,
- target: Au,
- X-ray beam stability: 0.6% (60 min).
- voltage supply: 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
$U_x = 40$ kV, $I_x = 40$ µA, time = 20 min.
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 anisotropy 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).

### New EBS for Intra-Operative Radiation Therapy

*Calculated angular distribution of X-ray dose rate in PMMA.*

- Non-swept electron beam. $U_a = 50$ kV, $I_a = 20$ µA.