Introduction

Overview and perspectives of ICS compact X sources

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Beam Dynamics at DIFA
Inverse Compton X sources
The Bologna proposal
Beam Dynamics at DIFA.

Research activity on non linear beam dynamics started in 85 in collaboration with CERN. We extended to Courant-Sneider theory to non linear betatron motion with Birkhoff normal forms 88.

Correction of multipolar errors and dynamic aperture.

Symmetry recovery with normal forms.
Current results of CERN collaboration

Change the tune to cross a resonance. Resonant extraction works experimentally being controlled with normal forms and adiabatic theory.

Dynamic aperture is related to the slow particles loss. A diffusion model with $D(J) = \exp(-J*/J)$ suggested by Nekhoroshev estimates allows extrapolations.
First EU network in beam dynamics

*Nonlinear Problems in beam dynamics and transport* (93-96).

Collective effects for intense beams (99-07)

Halo formation and collisional relaxation in collaborations with GSI (PIC and N body codes)
Since 08 we turned to laser plasma acceleration, which seemed promising for medical applications.

Simulation of proton and electron acceleration with our PIC code Aladyn in collaboration with LNF (Frascati) and ILIL (Pisa).
Synchrotron light imaging

Monochromaticity, space-time coherence, high brilliance allow to develop new techniques to obtain high quality images.

Images are obtained by absorption or by retrieval of information on the phase variations. The X refraction index is

\[ n = 1 + \alpha + i \beta \]

Imaginary part decreases faster with energy

In the 30-60 KeV range \( \beta = 10^{-3} \alpha \)

<table>
<thead>
<tr>
<th>E = 30 keV</th>
<th>( \alpha )</th>
<th>( \beta )</th>
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<tbody>
<tr>
<td>Adipose tissue</td>
<td>0.24 E-06</td>
<td>0.92 E-10</td>
</tr>
<tr>
<td>Soft tissue</td>
<td>0.27 E-06</td>
<td>0.13 E-09</td>
</tr>
<tr>
<td>Breast tissue</td>
<td>0.26 E-06</td>
<td>0.11 E-09</td>
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Comparison with X-ray tubes

**Synchrotron light:** space coherence + monochromaticity allow to detect interfaces and density variations in soft tissues.

Clinical targets: oncology, orthopedics, neurology.

**Microfocus:** almost pointlike source, wide energy spectrum. Phase contrast possible: lower quality, higher dose.
Inverse Compton X Sources

The basic idea is to transfer energy from electron beam to a photon beam, transforming light rays into hard X rays.

Electrons oscillate in the light beam as in a wiggler or undulator. Wavelength is $10^4$ times smaller ($1\mu m$ vs $1 \text{ cm}$).

X photons energy proportional to electrons energy square

Same X energy obtained with electron energy $1/100$ (ICS)

$$E_X^{\text{ICS}} \approx 4 hc \frac{\gamma^2}{\lambda_{ph}} \quad (ICS)$$

$$E_X^U \sim hc \frac{\gamma^2}{\lambda_u} \quad (undulator)$$
For head on collisions with $\lambda_{ph}=1 \, \mu m$ X energy of ICS

$$E_X(\text{KeV}) = 0.019 \, E_e^2(\text{MeV})$$

The beam divergence is a few mrad, to be compared with the smaller divergence of a SR source $\theta = 1/\gamma$.

ICS $E_e= 65 \, \text{MeV}$ $E_X= 80 \, \text{KeV}$ $\theta = 5 \, \text{mrad}$

ESRF $E_e= 6 \, \text{GeV}$ $E_X= 60 \, \text{KeV}$ $\theta = 0.1 \, \text{mrad}$
The Bologna proposal

To develop a compact system to produce high quality X rays

\[ E_{el} \leq 80 \text{ MeV} \quad E_{X} \leq 120 \text{ KeV} \quad \phi = 2 \times 10^{10} \text{ ph/s} \]

\[ E_{X} \leq 240 \text{ KeV} \quad \phi = 5 \times 10^{9} \text{ ph/s} \text{ second harmonic} \]

Main Target

Preclinical and clinical imaging

Secondary targets

Materials structure and detectors development

Non destructive analysis of mechanical samples

Characterization of cultural heritage samples
Road map

Conceptual design ready

Take off a few months after funding

Photoinjector + laser available on market

S band cavities 25 MV/m similar to STAR

Transport line (technical designed and machining)

X ray detectors and monitors (available)

Optimization for medical imaging
Thank you for participating
to this workshop