Dielectric Based Compact Accelerator for Industrial Applications

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Euclid Techlabs/Beamlabs

Euclid Techlabs/Beamlabs is a research and development company specializing in linear particle accelerators, ultrafast electron microscopy, and advanced material technologies for energy, defense, and medical applications. The company’s special interest is in the development of advanced high power components based on new “smart” materials and designs intended for beam physics and accelerator applications.

- 2 offices: Bolingbrook, IL and Gaithersburg, MD
- Close collaboration with National Labs: ANL, BNL, JLAB, FNAL, CERN, SLAC, NIST and universities.

www.euclidtechlabs.com
Key Euclid Technologies

- Ultra-compact low energy accelerator (dielectric based)
- Stroboscopic pulser for Transmission Electron Microscope
- Electron guns for accelerators: Photo-, thermo-, field emission (FE)- and SRF guns
- Ferroelectric based fast tuner
- UNC Diamond based FE and photo cathodes
- Accelerator components (RF windows, couplers...)
- Other beam physics instrumentation

Fast ferroelectric 400 MHz tuner successfully tested at CERN
L-band RF window for AWA ANL

5 GHz kicker for TEM, BES/NIST
Dielectric vs. Copper

Since 1948...

(a) Dielectric loaded accelerator

(b) Metallic disk-loaded accelerator

Dielectric accelerating structures
Introduction

With this talk, Euclid presents a portable lightweight and cost-effective ~MeV range accelerator that is compact enough to operate as a module for an easy stack-up to increase the deliverable radiation dose.

Focus on:

- the technology to replace the conventional copper linac with a significantly lighter and more compact dielectric accelerator.

- reduce the transverse size of the accelerating structure comparable to that of an ordinary pencil (factor ~5 OD, factor ~25 surface-wise).

- weight reduction of the structure

- weight reduction of the lead shielding
Key Challenges

Trade offs among dose rate - energy, and weight/ size
  • Parameters of rf source
  • Modulator (customized)
  • One charge operational time vs. battery time
  • Energy vs. shielding

Robust system performance in “real” environment
  • Solid RF coupling
  • Solid beam source
  • Robust beam alignment
  • Multipactor

Outer dimensions of the 250kW light-weight Magnetron, SFD352NM
Symmetry Waveguide

Symmetry WG was added.
• Field balance tuned by cells OD’s
• Coupling was good
• $S_{11} = -40\text{dB}$, $S_{12} = -80\text{dB}$, $S_{13} = -120\text{dB}$
  @ $F = 9.41\text{GHz}$
Focusing System Design Optimization

PPM along the tube plus PM blocks in the coupler

Focusing System

Magnetic field (T) on axis vs. Z (mm)

Beam tracking
Beam simulation in Astra

No Focusing Magnets

Transmission (to high energy) between 175 to 255 deg: 3.23%

With Focusing Magnets

Transmission (to high energy) between 175 to 255 deg: 31.79%

100% correlation with CST
Dose Estimation for 1MeV accelerators

The average Dose value is \( \sim 40 \text{ mGy/min} \), which can find its applications in radioactive material replacement in medical use, e.g. Electronic Brachytherapy Source.

As replacement of Ir-192

**Dose can be enhanced** using a higher energy beam, e.g. 3~4MeV.
1 MeV Dielectric Accelerator Engineering Design

~40% of the beam is bunched and accelerated to 1 MeV after 32 cm of acceleration.

<table>
<thead>
<tr>
<th>Input energy</th>
<th>20 keV</th>
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<tbody>
<tr>
<td>Input current</td>
<td>0.1 mA - 10 mA range</td>
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<tr>
<td>Number of cells</td>
<td>6</td>
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<tr>
<td>Total Length</td>
<td>32.70 cm</td>
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<tr>
<td>Total power</td>
<td>253.0 kW</td>
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<tr>
<td>Mean energy after this Section</td>
<td>1.01 MeV</td>
</tr>
<tr>
<td>Dielectric material</td>
<td>10-20 range</td>
</tr>
<tr>
<td>ID</td>
<td>4.0 mm</td>
</tr>
<tr>
<td>Max. OD</td>
<td>11.5 mm</td>
</tr>
</tbody>
</table>
Dielectric structure fabrication and bench test

Dielectric machining upgrade and dielectric parameters measurements.
Dielectric structure fabrication and bench test

A)

Bead-pull test

C)
High power rf and beam test

MeV e-beam Test Bunker
Modulator test at the test bunker
Field Emission UNCD cathode
Assembly
Summary

- Euclid’s 1MeV dielectric based compact accelerator prototype is being developed.
- Design and fabrication were complete, bench test and high power rf test were carried out.
- We finished 4MeV dielectric based design
- Exploring new applications in Isotope Replacement and Electronic Brachytherapy (EB)
Acknowledgments

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References:

2. Portable accelerator based X-ray source for active interrogation systems. US Patent 10,910,189
5. C. Jing et al. Applications of Compact Dielectric Based Accelerators. Proceedings of LINAC’12, Tel-Aviv, Israel, p. 150.