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Stephen M. Matthews

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INDUCTION LINEAR ACCELERATORS FOR COMMERCIAL PHOTON IRRADIATION PROCESSING *

by

Stephen M. Matthews
Lawrence Livermore National Laboratory
Mail Code L-389
Livermore, CA 94550

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INTRODUCTION

Irradiation processing technology is currently applied to thin films and surface treatments such as magnetic coating application to computer disks and curing labels on aluminum cans. This technology involves machine production of electron beams with relatively low energy of several tenths of a megavolt (MeV). Electron beams with higher energy at several MeV are used for cross linking polymers and in plastics manufacturing.

A number of proposed irradiation processes requires bulk rather than surface exposure with intense applications of ionizing radiation. Typical examples are irradiation of food packaged into pallet size containers, processing of sewer sludge for recycling as landfill and fertilizer, sterilization of pre-packaged medical disposals, treatment of municipal water supplies for pathogen reduction, etc. Volumetric processing of dense, bulky products with ionizing radiation requires high energy photon sources because electrons are not penetrating enough to provide uniform bulk dose deposition in thick, dense samples. Induction Linear Accelerator (ILA) technology developed at the

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Lawrence Livermore National Laboratory promises to play a key role in providing solutions to this problem.

REQUIREMENTS FOR PHOTON PROCESSING

Penetrating photons for radiation processing can be supplied as gamma radiation from megacurie (MCi) size isotope sources or as x-rays converted from machine produced electron beams. Conversion of electron beam energy to x-rays occurs when the beam impacts a thick metal plate. Electrons are absorbed on the back of the plate and a fraction of the beam energy is converted to x-rays that are emitted from the front. The remainder of the energy is converted to heat that must be removed from the plate.

Although the efficiency of the electron to x-ray conversion process increases with electron energy, it is still relatively low even at an energy as high as 5 MeV which is the maximum x-ray energy allowed for food processing. At 5 MeV the electron beam is converted to x-rays with an efficiency of approximately 7%. This small conversion efficiency is the root of the requirement for intense beams of 5 MeV electrons for commercial irradiation processing with x-ray photons. Few accelerators are commercially available that have the required capability.

The viability of machine produced irradiation sources for commercial bulk processing will occur when intense x-ray sources are available at a price comparable to a cobalt source with equivalent processing power. A one megacurie (MCi) cobalt source is equivalent in processing power to a 5 MeV x-ray source that is generated with a 150 kW electron beam. This estimate allows for the 7% conversion efficiency and the anisotropy of the x-ray production.

One commercially available machine capable of producing continuous, moderate intensity x-rays at 5 MeV is an RF accelerator manufactured by CGR-MEV. It produces a 40 kW electron beam and is equivalent to approximately 0.25 MCi of cobalt when operated in the x-ray mode. The CGR-MEV device was considered as a source for papaya processing at a planned food irradiation facility in Hilo, Hawaii. This device was rejected however, because of its $3.5 million price tag. Cobalt could be purchased for less than a half million dollars. An induction linear accelerator offers the only real possibility for achieving significantly higher electron beam power with energies at and above 5 MeV.

ILA TECHNOLOGY ACCOMPLISHMENTS AND GOALS

The ETA-II Induction Linear Accelerator at LLNL was designed to produce high beam brightness and high average power as an electron beam driver for FEL research. This machine first came on line in early 1988. Its design goal is to produce 10 MeV electrons with a beam power of 7500 kW for half second bursts. Although this machine has only been run at low power thus far, its magnetic drivers have been tested using simulated electrical loads. These tests indicate that the accelerator could be run continuously at 200 kW, and at ten times that power in bursts for several minutes.

An ETA-II type machine at 5 MeV could be constructed for research on the radiation processing of various substances. However, this machine would be expensive and not appropriate for commercial use. A number of design options are available that would provide a more suitable accelerator for commercial radiation processing than for FEL research.

A machine design optimized for commercial high power x-ray production rather than high beam brightness would be considerably less expensive than the ETA-II type. Although a serious engineering design study for this type of accelerator is badly needed, none has occurred.

Commercial manufacture of high average power ILA accelerators, although now in its infancy, appears to have a promising future. Pulsed Sciences Inc. is currently assembling a 20 kW, 1.6 MeV machine as a testbed for higher power. They hope to eventually produce multipurpose accelerators with average electron beam power in the 50-500 kW range at energies between 1 and 20 MeV. Osaka University is developing ILA technology as a driver for FEL research and is working with Toshiba in the design and construction of an appropriate accelerator. Progress to date includes module tests demonstrating 1 kA current pulses at 330 keV with 40 ns pulse widths. The eventual goal for their

FEL driver is to assemble these modules into an accelerator producing 3 kA pulses at 9 MeV, similar to the specifications of the ETA-II.