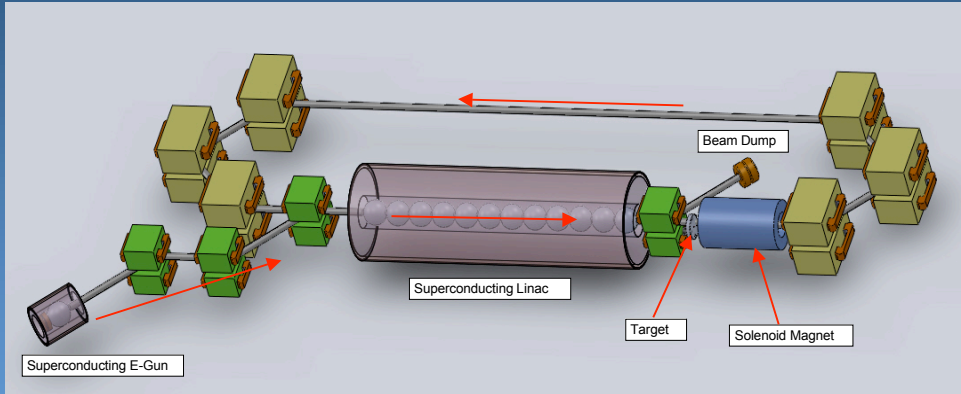


Superconducting RF linear accelerator to produce Mo-99 and Cu-67 for diagnostic and treatment



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Rendered layout of the isotope production energy recovery linac. The electron gun and the superconducting linac would be the same for a conventional single pass linac and the ERL. The ERL would have a special target. Once the beam passed through the target, it would be collected with the solenoid magnet, then transported back to the linac module using a lattice of magnets that are shown schematically. The entry merge and the beam dump are required. In order to achieve high average current, a superconducting electron gun and a superconducting linac are required. The layout illustrates one of the ERL's advantages: The beam dump is physically separate from the isotope target. In addition, the beam energy at the dump is below 5 MeV, so the neutron generation will be less than a conventional linac.

Technology

Electron linacs are being used to produce radio-isotopes. However, the linacs have limited power capability, and therefore, limited isotope production capability. In addition, the existing technology limits how much additional beam power can be added to increase capacity.

- The invention incorporates several technologies that would reduce the total power requirement for the linac, improve the isotope yield from the target, and reduce the isotope conversion time.
- The linac would use an energy recovery linac (ERL) technology in which the electron beam that is transmitted through the target is recaptured and re-injected into the accelerating structure.
- The recaptured beam transfers beam power to the injected electron beam, and reduces the amount of radio frequency (RF) power required to accelerate the electrons to energy.
- The linac needs to be only ~ 2 meters long. So the isotope linac will be compact in comparison to existing technology.
- The energy recovery is ~90 to 95%. The depleted beam power is dumped into a beam stop, which is physically separate from the target. This separation makes the heat removal more manageable than for existing linacs. The beam energy, target thickness, and recovered power will be optimized for maximum isotope yield. Finally the target will have a vacuum loadlock.
- An activated target can be removed from the target chamber and a new target installed without breaking vacuum or stopping the linac operation. The activated target will require robotic control, but this is well established technology.

To illustrate the advantage of an ERL isotope linac, a conventional linac is 40MeV beam energy. Below ~25MeV, the isotope yield is zero. So the yield is

$$Y = (40\text{MV} - 25\text{MV}) * \text{efficiency}$$

And the target power is: $P = 40\text{MV} * 0.1\text{A} = 4 \text{ MW}$

For an ERL, the lowest recovery energy is 35MeV, so the yield is

$$Y = (40\text{MV} - 35\text{MV}) * \text{efficiency}$$

But the power is $P = 5\text{MV} * 0.1\text{A} = 500\text{kW}$

The ERL current could be raised to 0.3A to increase the yield comparable to the conventional linac, but the power would still be only 1.5MW as compared to the 4 MW of target power for conventional linacs.

Interest in Invention

- Radio-isotopes have become essential in medical diagnostics and treatment. The predominant production process has been fission products in a nuclear reactor. However, many of the isotope reactors have been shut down, and commercial reactors that were planned to replace them have been cancelled.
- There is a resulting shortage of radio-isotopes, especially Tc-99. The Department of Energy (DOE), the International Atomic Energy Agency (IAEA), and numerous governments are developing plans to relieve the shortage.
- The electron linac described above aligns with recommendation that the best technology is an electron linac to produce photo-fission of U-238 to produce Mo-99.
- The invention has a number of advantages over existing linac technology: more compact, higher current for increased yields, improved thermal management of waste beam power, a continuous target feed, and multiple target capability.
- The linac will be configured for other isotope production, e.g. Cu-67, which requires similar energies to the Mo-99.

Markets

One Curie of Mo-99 is about \$320 on the open market. The estimated global requirement Mo-99 is estimated to be 12,000 6-day Curies per week (5,000 for U.S. use) (reference: National Academy Press). The annual growth rate is expected to be greater than 15% per year.

Commercial Readiness

- The compact, high power electron linac will have significantly less capital investment, approximately \$10,000,000 instead of \$150,000,000, and lower operating costs for a given isotope production.
- In addition to costs, production based on new commercial reactors will not realistically be ready until at least 2020.
- Energy recovery linacs have been demonstrated for light sources. The beam recovery for the isotope linac is different than for light sources, but manageable.
- Superconducting RF cavities and cryomodules are proven technology, but the specific cryomodule will need to be designed.
- The target vacuum loadlock would be designed with existing technology. The target thickness and beam energy would be optimized using existing accelerator and atomic physics computer.

Intellectual Property

An invention report has been submitted to Argonne National Laboratory and is in patent review.

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