New Gantry Design Uses CERN Magnet Technology in Innovative Cancer Treatment

A team led by CERN scientist and magnet expert Dr. Luca Bottura has developed a novel superconducting and lightweight gantry that can surround a patient and potentially revolutionize the delivery of hadrons for therapies, including cancer treatment. The new gantry design, GaToroid, is based on a toroidal magnet concept and bends the treatment beam without the need to rotate the structure.

Hadron therapy is an advanced radiotherapy technique using proton or ion beams to deliver precision treatment of tumors, sparing the surrounding healthy tissues from unwanted radiation. The intrinsic precision of this technique makes it particularly suitable for treating tumors in children or close to organs at risk. Furthermore, using rotating gantries to move the beam around the patient, medical doctors can irradiate the tumors from different angles, sparing even more of the surrounding tissue.

The idea came to Bottura after a realization of sorts. "This is exactly the opposite of what is attempted in magnetic shields for astronauts, where the idea is to divert particles away from the astronauts with a toroidal field," Bottura explained to ***Cold Facts***. "In the case of GaToroid the idea is to divert particles towards the patient, using the same toroidal field, but with reversed polarity."

Gantries are complex pieces of engineering, representing a considerable part of the installation costs and size, or footprint, in hadron therapy. For carbon ions, there are only two gantries in the world. The first one is at the Heidelberg Ion-Beam Therapy Center in Germany, measuring 25 meters in length and weighing more than 600 tons. The second, in Chiba, Japan, is a superconducting gantry with a reduced size and weight, but with the added challenge of a rotating cryogenic system. While the therapeutic interest for carbon or other ions heavier than protons is increasing, the enormous size of today's gantries, combined with the lack of viable standard technological solutions, poses relevant constraints on future hadron therapy facilities.

The GaToroid gantry comprises a set of fixed, discrete superconducting coils constituting the toroidal magnet and a bending device at the entrance of the structure to direct the beam at the correct angle. By using superconductors, GaToroid will substantially reduce weight and footprint compared to conventional gantries, especially for ion beams. The device also has the added benefit of not exposing the patient to the effects of a magnetic field.

Speaking at a CERN Knowledge Transfer seminar, Bottura explained that the GaToroid takes a hadron beam from an accelerator and first passes it through a vector magnet. This magnet adjusts the direction of the beam in the X and Y planes. The beam is then sent at the desired angle to a torodial magnet that is made up of superconducting toroidal coils, 16 of them, where it is "bent" and directed to the specific inter-coil space. As GaTaroid only relies on these magnets and not the act of physically repositioning the gantry, it allows doctors to change delivery direction and speed extremely quickly, a feature not possible with traditional gantries.

"The beam extracted from the accelerator is directed by what we call a vector magnet towards the toroid, with an angle and direction that can be predetermined so that the beam is bent towards the desired location—the organ to be irradiated," Bottura says. "With proper design of the toroidal field, and changing the entry point with the vector magnet, it is possible to have a toroidal magnet system that operates in steady state, accepting beams of largely different energy and direction."

Since this system works in steady state with no rotation, it can fully exploit the potential of superconductors, having no limitations by current or the system's movement. By selecting the impinging angle of beams with different momentum values, it is possible to reach different spots if beams have the same entry point, or to get a focusing effect if beams enter the magnet from different angles.

GaToroid is meant to be lightweight: if used with proton beams, the structure would have an outer diameter of about 3.2 meters, for a total weight estimated around 12 tons. For carbon ion beams, the outer diameter would be on the order of 5 meters, for a total weight of around 50 tons. This represents a substantial weight reduction compared to conventional gantries, which weigh around 100 tons for protons and over 350 tons for carbon ions.

"The objective is to have a system which is competitive in cost, has a reduced footprint and a lighter weight. This is possible because there is no large rotating structure. This reduces the time required for irradiation because there is no need to ramp the magnets and rotate them. It also minimizes the need to move the patient between dose deliveries thanks to irradiation from multiple directions," Bottura said. "An ideal solution would be to have an MRI-like situation, where the patient is prepared, moved in position, treated and then removed from the treatment area." ■