High Gradient Induction Cell

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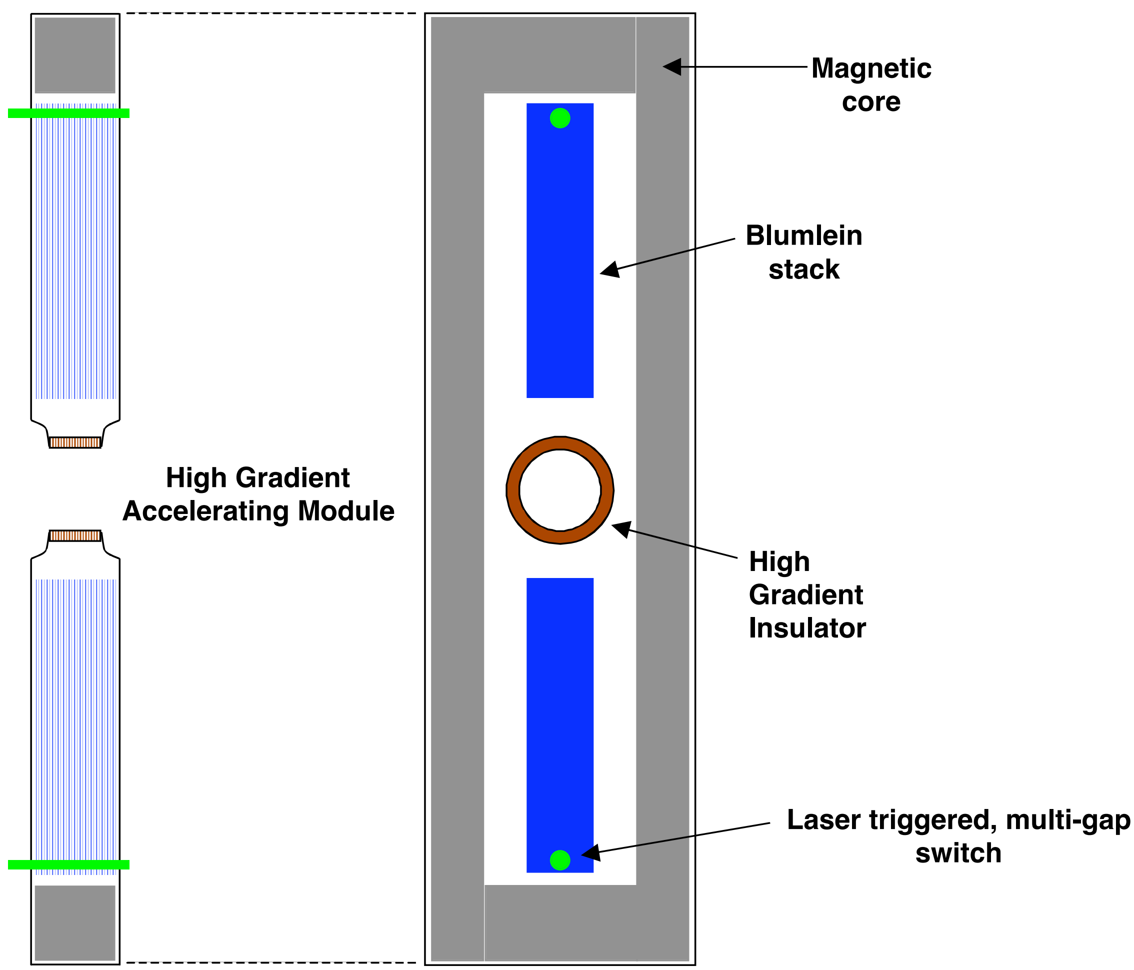
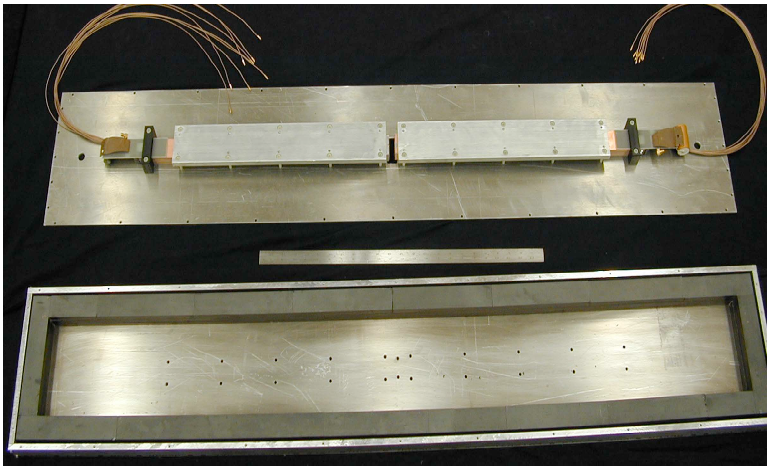
A concept being developed for high current electron beams may have application to HEDP and is described here. It involves the use of planar Blumlein stacks placed inside an induction cell. The output end of the Blumlein stack is applied across a high gradient insulator (HGI)[1]. These insulators have been used successfully in the presence of kilo Ampere-level electron beam currents for tens of nanoseconds at gradients of 20 MV/meter.

At the switch end of the Blumlein (the end opposite the output end) a voltage erects upon closure of the switches. A magnetic core material is used to prevent the discharge of the lines from the switch end. The system under active development uses a laser-triggered, multi-gap gas switch. An illustration of the concept is shown below.



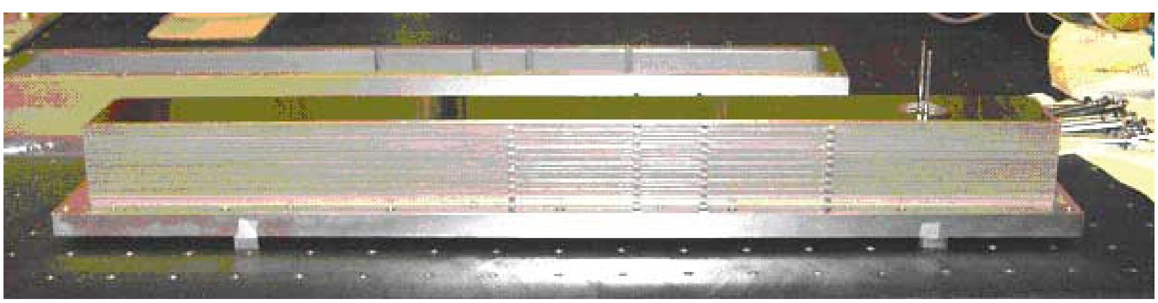
Proposed high gradient induction module shown from the side (left) and from the top (right). The high gradient insulator is deliberately made shorter than the cell in order to provide room for a short magnetic focusing element.

This goal for this cell is an average accelerating gradient of 3-5 MV/meter. The concept shown above employs two Blumlein stacks and a ferrite core for isolation. The cell architecture has been verified by constructing a low voltage model that uses avalanche transistors as switches and a material called RT-Duroid (a commercially printed circuit board laminate that has a relative dielectric constant of 10.2 and is available in large sheets) for the Blumleins. The working model is shown below.



The scale cell model shown with the top metal cover removed. The ferrite isolation in the form of "bricks" can be seen in the bottom portion of the picture while the two Duroid Blumlein stacks can be seen in the upper half of the picture. This cell produced an output pulse of 10 ns.

At the present time a high voltage test is underway using a Duroid stack of 20 Blumleins and the multi-gap laser triggered switches. The stack should produce a 20 ns wide output pulse.



A Duroid stack of 20 Blumleins approximately one meter in length and 11.5 cm high (with end plates). The individual lines are charged from 20 – 30 kV.

We have been developing a castable dielectric material with a relative dielectric constant of about 40 that has large bulk breakdown strength. We were recently able to cast a large size stripline using this material. Use of this material should permit a factor of two reduction in the lateral size of the induction cells. The material is a suspension of high dielectric constant material in a plastic-like binder and can be cast into almost any desired shape.

A one-meter long stripline of the castable dielectric. This line has a relative dielectric constant of about 40 and is relatively flexible.

This cell concept has the potential to increase the average accelerating gradient of electron induction machines by about an order of magnitude but has several disadvantages. In contrast to the usual induction cell, the pulsed power drive is internal to the cell and is fixed by the stripline and core geometry; it cannot be adjusted externally. This disadvantage can be somewhat offset by tapering the Blumleins to arrive at a desirable output pulse shape. Also, the core volume tends to be rather large, as it must surround the Blumleins.

Because the core is not driven uniformly magnetic flux does not symmetrically flow in the core; some of the flux leaves the core and closes through the stripline leading to a reduction in core impedance over what would be the case for symmetric drive. In the scale model, the output pulse into a matched load was approximately two thirds of the charge voltage due to the loading of the lines by the core. This problem can be reduced by the use of higher dielectric stripline material.

In order to preserve as high an accelerating gradient as possible relatively little space is available for focusing elements. This space is made available by increasing the gradient on the HGI as compared to the cell interior. The length of the HGI may be made smaller than the cell length by a factor of 2 to 4 leaving over the half of the beamline available for focusing elements. While this appears adequate for electron beam applications it may not be enough space for HEDP.

References:

1. Sampayan, S., Vitello, P., Krough, M., and Elizondo, J., IEEE Trans. Dielectrics and Electrical Insulation 7 (3): 334-339 June 2000.