

**ROBERT MURATORE, '88**



Dear Dr. Goldberg,

Congratulations on the first issue of Physics Matters newsletter. I enjoyed hearing about the department and have attached my own contribution for a future issue.

Best regards,  
Robert Muratore

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Robert Muratore, Ph.D.  
Principal Member of the Research Staff  
Frederic L. Lizzi Center for Biomedical Engineering Riverside Research  
Institute  
156 William St Fl 9  
New York NY 10038-2609 USA  
+1 212 502 1701 telephone  
+1 212 502 1729 fax  
<mailto:muratore@rrinyc.org>  
[www.rri-usa.org](http://www.rri-usa.org)

Large, Cheap Damage Ratios for Biomedical Therapy - By Robert Muratore \*88

Two decades ago, I was a graduate student and then a post-doctoral fellow in the Department of Physics at Syracuse University, studying biophysics with Professor Ted Kalogeropoulos. Four decades earlier, Robert R. Wilson had proposed the use of proton beams for medical therapy. Proton beams deposit most of their energy at the end of the

particle track, whereas other energy sources typically deposit most of their energy near the proximal target surface. Thus, the ratio of target tissue damage to healthy tissue damage is very high for protons. Ted realized that antiprotons (discovered by his own dissertation advisor Emilio Segre) could provide a dramatic increase in the damage ratio because of the annihilation events at the end of their tracks. The pi mesons emanating from an annihilation vertex could precisely triangulate the peak energy deposition region, which depends on the initial particle velocity and the density profile along its track, adding an imaging capability. I refined the models of this process, and developed strategies for a further doubling of the damage ratio. In part due to the costs of developing a transportable storage ring, the antiproton stereoradiography (ASTER) program never materialized in the clinic.

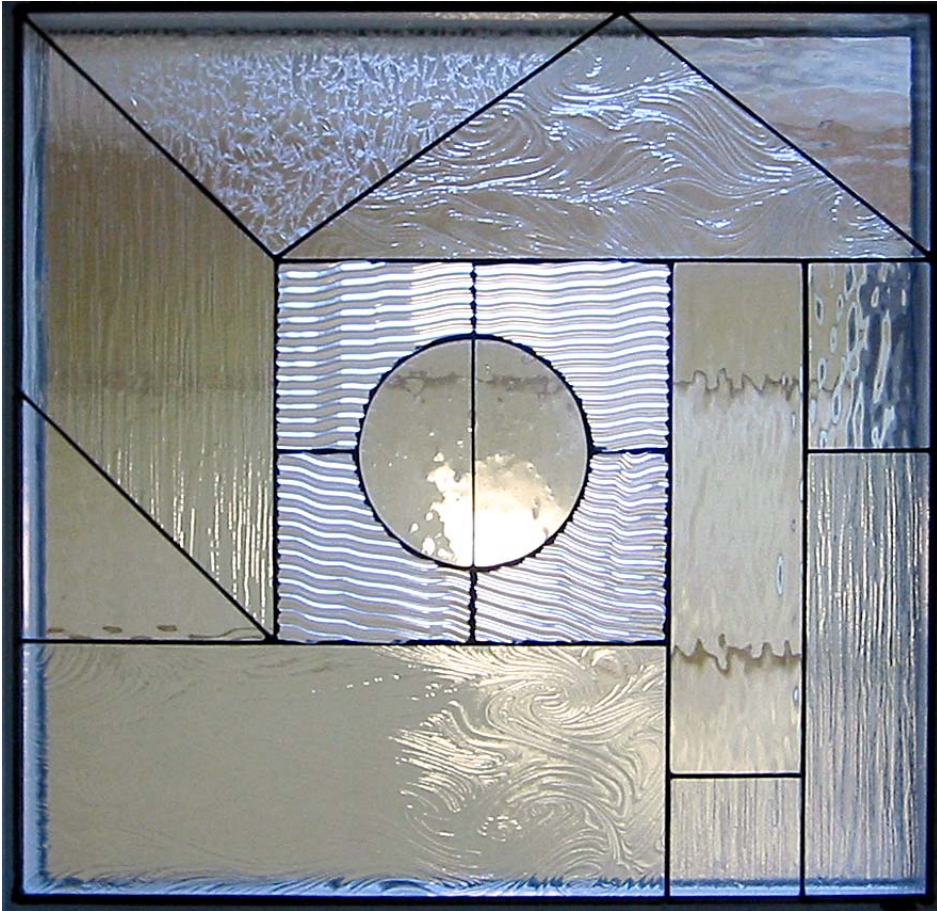
Currently, I am Principal Member of the Research Staff at Riverside Research Institute in New York City. My research group is funded mostly by the National Institutes of Health. We focus on biomedical applications of ultrasound, such as blocking the reentrant signal pathways in the cardiac ventricles that are responsible for ventricular arrhythmias, the chief cause of cardiac failure. Generally, the aims of my research are very similar to the work in which I participated at Syracuse: to use an external energy source to locate aberrant tissue regions in the human body, and then to "turn up the volume" to therapeutic levels and destroy that tissue. High intensity focused ultrasound (HIFU) is cheap (especially compared to antiprotons), and is becoming increasingly used by surgeons.

On the other hand, the wave equations which govern ultrasound are beastly compared to the Monte Carlo particle trajectories of antiprotons. I have been working on a comprehensive model of ultrasound-tissue interaction so that HIFU can be applied with an understanding of the underlying mechanisms. Like charged baryon beams, HIFU offers a large damage ratio, but the reasons are different. HIFU damage arises from absorbed ultrasound energy, and the absorbed energy scales with intensity, which is much higher in the focal region.

Because of the uncertainties of tissue density distributions, HIFU treatment planning based on a priori models is imprecise. As with the pi mesons that provided feedback for antiproton therapy, some sort of feedback is required for HIFU. Treated tissue has very similar acoustic properties to untreated tissue, so "old, cold" lesions can be difficult to locate with conventional ultrasound imaging.

The proteins that structure tissue are shaped by tertiary bonds with a strength of about  $1/2$  eV. This is infrared, and applying heat (e.g., through ultrasound absorption) to tissue breaks these bonds and denatures the proteins. This process is commonly called cooking, and results in tissue that is more friable ("fry-able, then friable") but stiffer. It is possible to determine the regions of stiffer tissue with elastography, in which an external force is applied to the tissue and strain maps are obtained by tracking tissue motion. Appropriately, ultrasound is often used for tracking.

The acoustic radiation force that accompanies ultrasound turns out to be a very effective probe of tissue elasticity. We call this technique RAVE (remote acoustic viscoelastography).



Art Glass: Archimedes