AbstractID: 9159 Title: Innovative Instrumentation for Resonant Cancer Theranostics

Purpose:

Most current diagnostic and therapeutic X-ray techniques use nonspecific, broadband continuum radiation. By taking advantage of *resonant absorption complexes* in heavy-element-tagged nanoparticles or contrast agents delivered to disease sites, we can use tunable, narrow energy bands for both therapy and diagnosis (theranostics) that is extremely efficient and minimizes radiation exposure to neighboring tissue.

Materials and Methods:

We use an electron beam ion trap (EBIT) as the source of tunable, monochromatic X-rays for imaging and therapy and a cryogenic x-ray microcalorimeter to form spectroscopically resolved images. The high resolving power ($E/\Delta E > 2000$) and low background of the microcalorimeter are essential for verifying the resonant absorption signatures predicted by our relativistic R-matrix calculations. The microcalorimeter is used to tune the X-ray emission from the EBIT plasma to the band of resonant absorption lines in the tagged nanoparticles. The unprecedented signal to noise of the microcalorimeter means that it can identify line emission with less than 20 counts per energy resolution element, making the eventual dose necessary for diagnostic imaging potentially very low.

Results:

We describe the EBIT and the microcalorimeter with emphasis on the X-ray energy range required by cancer theranostics. Preliminary studies with the microcalorimeter demonstrate that it can image atomic fingerprints of heavy-element uptake such as gold nanoparticles that can be embedded in malignant tissue.

Conclusions:

We discuss two key component technologies for atomic level theranostics : The electron beam ion trap is a *smart* x-ray source capable of generating monoenergetic resonant X-rays that maximally interact with the matching high-Z contrast agent or nanoparticles; the spectroscopic microcalorimeter is a “zero-background “detector by design and can discriminate resonant signatures with 10 times better resolution than any other X-ray spectrometer, thus providing very high sensitivity for detailed mapping of elemental distributions such as gold nanoparticles and platinum-based chemotherapeutic compounds.