

**Title of Thesis**

Name

University Department

University

Master's Thesis Proposal

Date

Advisor: \_\_\_\_\_

## ABSTRACT

In the proposed work, the gamma emission and neutron scattering cross sections for erbium will be studied via the  $(n,n'\gamma)$  reaction at incident energies in the 0.2 to 1.0 MeV range. The measurements will be conducted with the University of Massachusetts Lowell Radiation Laboratory's 5.5-MV Van de Graaff accelerator. Erbium is used as a burnable poison in a nuclear reactor. Burnable poisons are characterized by a large ( $\sim 1000$  b) thermal neutron capture cross section. They are used in elemental form, e.g. elemental erbium, although only one isotope of erbium,  $^{167}\text{Er}$ , has the required large cross section. Appropriate burnable poisons are found throughout the periodic system. The best known candidates are B, Hf, Er, Gd.

## INTRODUCTION

Today, more than ever, the need for safe and efficient power sources is recognized. Nuclear power is believed by many to be the best choice for the power source of the future. New advancements in this field are continually being discovered. However, in light of current public opinion, radioactive waste management is perhaps the most important concern for the nuclear power industry [1]. In addition to the waste created by reactors, the decommissioning of nuclear weapons has led to a supply of salvaged plutonium. New reactor designs have been proposed that would burn substantial amounts of the plutonium while generating electric energy [2,3]. The technique of adding burnable poisons to reactor fuel addresses and improves all of these areas of concern.

Erbium is one of the better choices for use as a burnable poison. Erbium has one isotope (Er-167) with a neutron capture cross section of kilobarns, which increases with temperature. This ensures a strong negative temperature coefficient of reactivity [4]. The end results are

increased core lifetime, a flatter reactivity-to-time curve, and a reduction in the excess plutonium.

### **PREVIOUS WORK**

Nuclear data for erbium are sparse; specifically fast neutron elastic and inelastic scattering cross sections and gamma emission cross sections are poorly known [5]. This has led some investigators to "borrow" cross section data from neighboring nuclides, e.g. B. D. Murphy [6], who used Gd gamma emission cross sections in lieu of Er cross sections. To remedy this unfortunate situation, elastic and inelastic neutron scattering cross sections and also gamma emission cross sections for erbium will be determined.

The measurements proposed are analogous to recent studies at Lowell. Y. J. Ko *et al.* [7] has reported neutron inelastic scattering measurements via the  $^{169}\text{Tm}(n,n'\gamma)$  reaction. Neutron energies covered the range from 0.2 to 1.0 MeV and gamma rays above 100 keV were studied. Gamma-production cross sections for 16 gamma rays were reported and inferred cross sections for ten levels were presented.

### **PROPOSED WORK**

There are two common experimental techniques that would be suitable for this type of research, namely the  $(n,n'\gamma)$  technique and the  $(n,n')$  technique [7,8]. The first is an indirect measurement observing the de-excitation gamma rays, while the second is a direct measurement observing the scattered neutrons. The  $(n,n'\gamma)$  technique was chosen over the  $(n,n')$  technique because of the multitude of isotopes in the erbium sample (see Table 1), and the superior resolution of the high-purity germanium (Ge) detector.

Table 1. Atom percent abundance for the isotopes of erbium [10].

ATOMIC WEIGHT	ATOM PERCENT ABUNDANCE
162	0.14%
164	1.61%
166	33.6%
167	22.95%
168	26.8%
170	14.9%

The first step of the  $(n,n'\gamma)$  technique is the observation of de-excitation gamma rays following inelastic scattering. The gamma-ray spectrum will be represented by a linear combination of Legendre polynomials. The spectrum will be obtained at angles chosen to reduce the polynomial expansion to a simple form. Then the inelastic level cross sections will be deduced from the known level scheme and branching ratios.

A high purity germanium (Ge) detector will be used to detect the de-excitation gamma rays from the erbium sample. An NaI(Tl) annulus will be used to suppress signals caused by Compton scattered gamma rays.

To determine optimum values for geometric parameters such as the dimensions of the scatterer and the distance between target and the scatterer, a computer program will be used to

simulate the experiment. Corrections will be applied for finite sample effects and the attenuation of neutrons and gamma rays in the sample.

It will be possible to carry out this research because the accelerator group has at its disposal a specially designed, pulsed, type CN Van de Graaff accelerator provided with a Mobley post-acceleration compression system. This machine is capable of providing proton bursts with a width of 0.5 nanoseconds or less (with the Mobley buncher), with a repetition frequency of 5 MHz, and with a typical average proton current of 10  $\mu\text{A}$ . However, the time resolution of the HPGe detector is poor, so it is not necessary to use the buncher. Therefore, resolution of 5 to 10  $\mu\text{s}$  will be sufficient. Thin metallic lithium targets evaporated onto tantalum backings will be used to generate nearly monoenergetic neutrons via the  ${}^7\text{Li}(p,n){}^7\text{Be}$  reaction.

## **CONCLUSION**

The (n,n' $\gamma$ ) technique is an efficient method for determining the inelastic neutron cross section for erbium, specifically  $^{167}\text{Er}$ . This technique is used routinely at the UML accelerator facility- with a high degree of accuracy. The proposed experiment will contribute cross section measurements that are desperately needed for improving the science of using erbium as a burnable poison in reactor fuel. This will help even out the excess reactivity over the entire fuel cycle, making reactors safer, more efficient, and reducing the amount of extra plutonium.

## **COLLABORATION**

This research is being conducted in collaboration with \_\_\_ and \_\_\_ at \_\_\_ National Laboratory. Specifically, the collaboration will include...

## REFERENCES

[1] Alan Baxter, Carmelo Rodriguez, Matt Richards, Jozef Kuzminski, “Helium-Cooled Reactor Technologies for Accelerator Transmutation of Nuclear Waste”, p. 594.

(<http://www.nea.fr/html/pt/docs/iem/madrid00/Proceedings/Paper72.pdf>)

[2] Hartmut U. Wider, Johan Karlsson, Alan V. Jones, “Aspects of Severe Accidents in Transmutation Systems”, p. 501

(<http://www.nea.fr/html/pt/docs/iem/madrid00/Proceedings/Paper46.pdf>)

[3] D. Ridikas, G. Fioni, P. Goberis, O. D’eruelle, M. Fadil, F. Marie, “Critical and Sub-Critical GT-MHRs for Waste Disposal and Proliferation-Resistant Fuel Cycles”, p. 918.

(<http://www.nea.fr/html/pt/docs/iem/madrid00/Proceedings/Paper71.pdf>)

[4] Radomir Ilic, “Zirconium Hydride (ZrH)” University of Maribor, Faculty of Civil Engineering, Postgraduate Course of Nuclear Technology, p. 25.

(<http://www.rcp.ijs.si/~zagar/IJS/ZrH.pdf>)

[5] D. Hittner, “Industrial Perspective on Nuclear Data”, Framatome ANP, International Conference on Nuclear Data for Science and Technology, Tsukuba, Japan, - October 2001, abstract 12A2(948), p. 10.2-O-5 in the Book of Abstracts distributed at the conference.

[6] B. D. Murphy, Oak Ridge National Laboratory Report ORNL/TM-13170/V1, p.2.

[7] Y. J. Ko, J. J. Egan, G. H. R. Kegel, D. J. DeSimone, P. N. Seo, P. G. Young, “Thulium-169 neutron inelastic scattering cross section measurements via the  $^{169}\text{Tm}(n,n'\gamma)$  Reaction”, Nuclear Physics A 679, 147 (2000).

[8] P. N. Seo, “Fast Neutron Scattering Cross Sections for  $^{159}\text{Tb}$  via the  $(n,n'\gamma)$  and  $(n,n')$  Techniques”, Ph.D Dissertation, University of Massachusetts Lowell, p. 9, unpublished, 2001.

[9] Chart of the Nuclides, 15<sup>th</sup> edition, 1996, p. 38, General Electric Co. and KAPL, Inc.