LASER SPECTROSCOPY OF NUCLEAR REACTION PRODUCTS: RECENT RESULTS AND FUTURE PROSPECTS

J. BEHR, S. CAHN, J. DAS\textsuperscript{a)}, G. GWINNER, C.H. HOLBROW\textsuperscript{b)}, T. LAURITSEN\textsuperscript{c)}, L.A. OROZCO, S. SHANG\textsuperscript{d)}, J. SCHECKER\textsuperscript{e)}, G.D. SPROUSE and F. XU

\textit{Physics Department, State University of New York, Stony Brook, NY 11794-3800, U.S.A.}

Laser spectroscopic observations of nuclear reaction products produced with intensities of less than $10^4$ atoms/second are now possible with several different methods. We describe the recoil into gas method which has recently been successful. This method is not Doppler-free, but can give reasonable spectra if the resolution requirements of the spectra are not too high. It has the great advantage that it very efficiently uses the atoms, and spectra have been observed with primary production rates of less than $10^3$ atoms/sec. Our recent work has concentrated on developing the recoil into gas method for the refractory element Hf. In order that the atoms could be cycled to produce many fluorescence photons, nitrogen and hydrogen impurity gases were added to the argon buffer gas to quench metastable levels to the ground state. In this way spectra could be obtained with fluxes of $10^4$ atoms/second. Future prospects for trapping radioactive atoms in a magneto-optic trap will be discussed.

1. Introduction

The sensitivity of laser spectroscopy \cite{1} has allowed detailed measurements of exotic nuclei that are very far from stability. The systematic studies that have been done over long chains of isotopes have significantly aided in our understanding of nuclear structure. There are remaining unexplored areas which will require further developments in experimental technique in order to study in detail. These developments proceed along several lines. More intense sources of unstable nuclei are being considered at various facilities, but in addition specific methods to circumvent some of the limitations of the standard collinear apparatus are being studied.

\textsuperscript{a)} Present address: KVI, Groningen, The Netherlands.
\textsuperscript{b)} Present address: Colgate University, Hamilton, NY, U.S.A.
\textsuperscript{c)} Present address: Argonne National Laboratory, Argonne, IL, U.S.A.
\textsuperscript{d)} Present address: Physics Department, University of California, Berkeley, CA, U.S.A.
\textsuperscript{e)} Present address: Los Alamos National Laboratory, Los Alamos, NM, U.S.A.
The new developments of state selective ion and atom detection with the collinear technique have been very well covered by the previous paper of Dr. Lievens, and we wish to focus on an old method which has recently had some success, namely the recoil into gas method. The recent work is now well documented in the literature [2,3], so that we will only outline the method, and then point out some of the specific aspects which are often not communicated well in formal publications.

2. Recoil into gas method

The basic idea of the recoil into gas method is very simple in concept, but requires extreme care in practice. An inert buffer gas is used to stop nuclear reaction products in the vicinity of a laser beam which then induces fluorescence in the atoms. The buffer gas serves to retard the diffusion of the atoms to the walls, so that multiple excitation cycles can increase the fluorescence yield from a single atom. The motivation for using this Doppler limited method is that the atoms can be efficiently deposited in less than $10^{-8}$ s into the laser beam without any consideration of melting point or volatility. However, questions of background suppression, neutralization, and diffusion times must be addressed to successfully observe the fluorescence.

Fig. 1. Arrangement of target and beam stopper.

The target arrangement that we used is shown in fig. 1. Because heavy ion fusion evaporation reactions are quite selective, an isotope separator was not necessary, and this allows for efficient use of the limited number of atoms. The fusion products from the reaction are carried out of the target by the momentum of the beam particle. Because of multiple Coulomb interactions in the target, the slow recoil nuclei are scattered to much larger angles than the fast beam particles, and an angular separation can be made. If additional separation is needed, Au foils can be added to spread out the recoil nuclei to larger angles. The thickness of material in the target, gas windows and buffer gas must be carefully adjusted to maximize the concentration of recoil nuclei in the vicinity of the laser beam. Small adjustments in the gas are usually made to optimize the signal. The pressure chosen for the