EXPERIMENTAL METASTABLE LIFETIMES AT DESIREE STORAGE RING – FIRST STOP: BARIUM

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Outline

❖ Parity forbidden lines as probes of astrophysical conditions
❖ Lifetime measurements through laser probing, and pumping, of stored ions
❖ Preliminary results for Ba II
Forbidden lines as probes of conditions of astrophysical plasmas

Strontium Filament of Eta Carinae showing forbidden lines from iron group elements and SrII.
Forbidden lines as probes of conditions of astrophysical plasmas
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Singly ionized barium - Ba II

Singly ionized barium has two metastable states in the 5d configuration.

Expected lifetimes:
- $5d^2 D_{5/2} : 32\,s$
- $5d^2 D_{3/2} : 83\,s$
DESIREE storage rings

DESIREE is a cryogenically cooled compartment under ultra-high vacuum. The ions are stored and directed with electrostatic elements.

DESIREE storage rings

O.A.: Optical access for laser beams
QD: Quadrupole doublets
D: 10° Deflector

RAES: Resistive Anode Encoder - S ring
ID: Imaging detector
F.C.: Faraday cup

Ba+ source
Magnet for mass spectrometry

overlapping section

PMT

Shutter 1
M squared
Freq. doubled

Shutter 2
Dye laser
Experimental technique for lifetime measurements

$6s^2^2S_{1/2}$

$^2P_{3/2}$

$^2P_{1/2}$

$6p$

$^2D_{5/2}$

$^2D_{3/2}$

$5d$

$649\text{nm}$

$493\text{nm}$

$2S_{1/2} = 2S_{1/2}$

$2P_{3/2} = 2P_{1/2}$

$2D_{5/2} = 2D_{3/2}$

$[2.0 \mu m]$
A red laser at 649 nm probes the population of the metastable $5d^2D_{3/2}$ level.
Experimental technique for lifetime measurements

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- Repeated probing of the metastable population, with different time delays after pumping, build up the lifetime curve.
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- A blue laser at 493 nm pumps all ions (back) into the metastable $5d^2D_{3/2}$ level.
- Repeated probing of the metastable population, with different time delays after pumping, build up the lifetime curve.
- Normalization and monitoring of the changes in number of stored ions population is crucial.
Experimental technique for lifetime measurements

\[ 2S_{1/2} = 2S_{1/2} \]

\[ 2P_{3/2} \quad 6p \]

\[ 2P_{1/2} \]

\[ 2D_{5/2} \quad 2D_{3/2} \quad 5d \]

493nm

649nm

6s^2S_{1/2}

[2.0\mu m]
Preliminary results for Ba II: $5d^2D_{3/2}$

The pump-probe technique has successfully been developed for the Ba+ ions at DESIREE.

- Ion beam lifetime measured to 500s.
- Effect from repopulation and cascades is very small.
- An uncertainty of a few percent can be reached for ideal systems.
- For $5d^2D_{3/2}$ we reach a lifetime $\tau = 80 \pm 1$ s

Technique will be applied to more complex systems such as FeII and Ni II with astrophysical importance.
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Available for application: http://www.desiree-infrastructure.com
Parity forbidden lines in near-IR

An important class of infrared lines are parity forbidden transitions (E2 and M1), observed in nebula and low density plasmas.

*Low transition rates (A around 1 s\(^{-1}\))*

*Long radiative lifetimes (several seconds)*

*Sensitive to collisions*

Have relied on calculated transition rates, but can be measured using selective methods at storage rings (e.g. CRYRING and DESIREE @ Stockholm university, Sweden) combined with astronomical observations of low-density plasmas (Eta Carinae).
Previous results

❖ **Experiments:**
Gurell (2007) : 89.4(156)
Nagourney (1997) : 79.8(46)

❖ **Theory**
U.I. Safranova (2017) : 81.4(14)
Gurell (2007) : 82.0
B. K. Sahoo (2006) : 80.086(714)
V. A. Dzuba (2001) : 81.5
Doppler Tuning of the ion beam through acceleration
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