High sensitivity laser spectroscopy of rare earth atoms in solid noble element matrices

➤Matrix isolation;

➤Solid Neon and rare earths;

➤Laser spectroscopy – QC concept-based;

Matrix isolation

➢Trapping of active molecules in an inert solid matrix;

➢Condensation of a gas mixture of the matrix and the active species;

➢At low temperatures – inhibition of the trapped molecules diffusion, immobilization within the inert matrix;

➢Chemical inertness of the matrix → low interference with the electronic structure of the guest atoms → free atoms/molecules.

s-Neon

➤ Atomic weight: 20.1797;

➤ Density at tp: 1.444 g/cm^3; T = 24.562 K, p = 430 mbar;

➤ fcc crystal structure under zero pressure at 4 K.

• For a doped Neon crystal:

➤ 0.01 % guest atoms → 5.4 x 10^{17} cm^{-3}; (1.4 x 10^{18} cm^{-3} in YLF)

➤ 1 % guest atoms → 5.4 x 10^{19} cm^{-3}. (1.4 x 10^{20} cm^{-3} in YLF)

10^{15} cm^{-1} [New J. Phys. **17** (2015) 113025];

➤ $N_{axion\ events}$ ~ $N_{guest\ atoms}$

➢ Vapour pressure: at 1595 K, 10^{-2} mbar;

➢ e$^-$ configuration:

$(1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6)\ 4f^4 6s^2 \rightarrow {}^5I$

$(4f^4)^* \rightarrow 4f^4$

6s6p $\rightarrow$ 6s^2

Configuration	Term	J	Level (cm^{-1})
$4f^4 6s^2$	^5I	4	0.000
		5	1128.056
		6	2366.597
		7	3681.696
		8	5048.602

➢ Max radiative lifetime: 481 ns [J. Phys.B: At. Mol.Opt.Phys. **44** (2011) 225001] $^5H^0_4$

➢Possible complication:

Odd- and even-parity configurations overlap in wide energy range
→ambiguity of the results

[J. Phys. B: At. Mol. Opt. Phys. 37 (2004) 1381–1389]
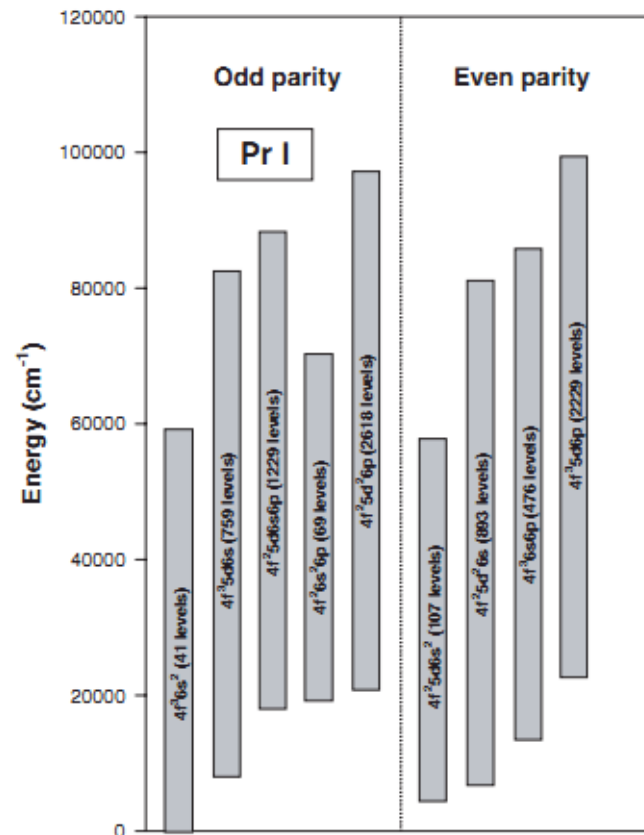
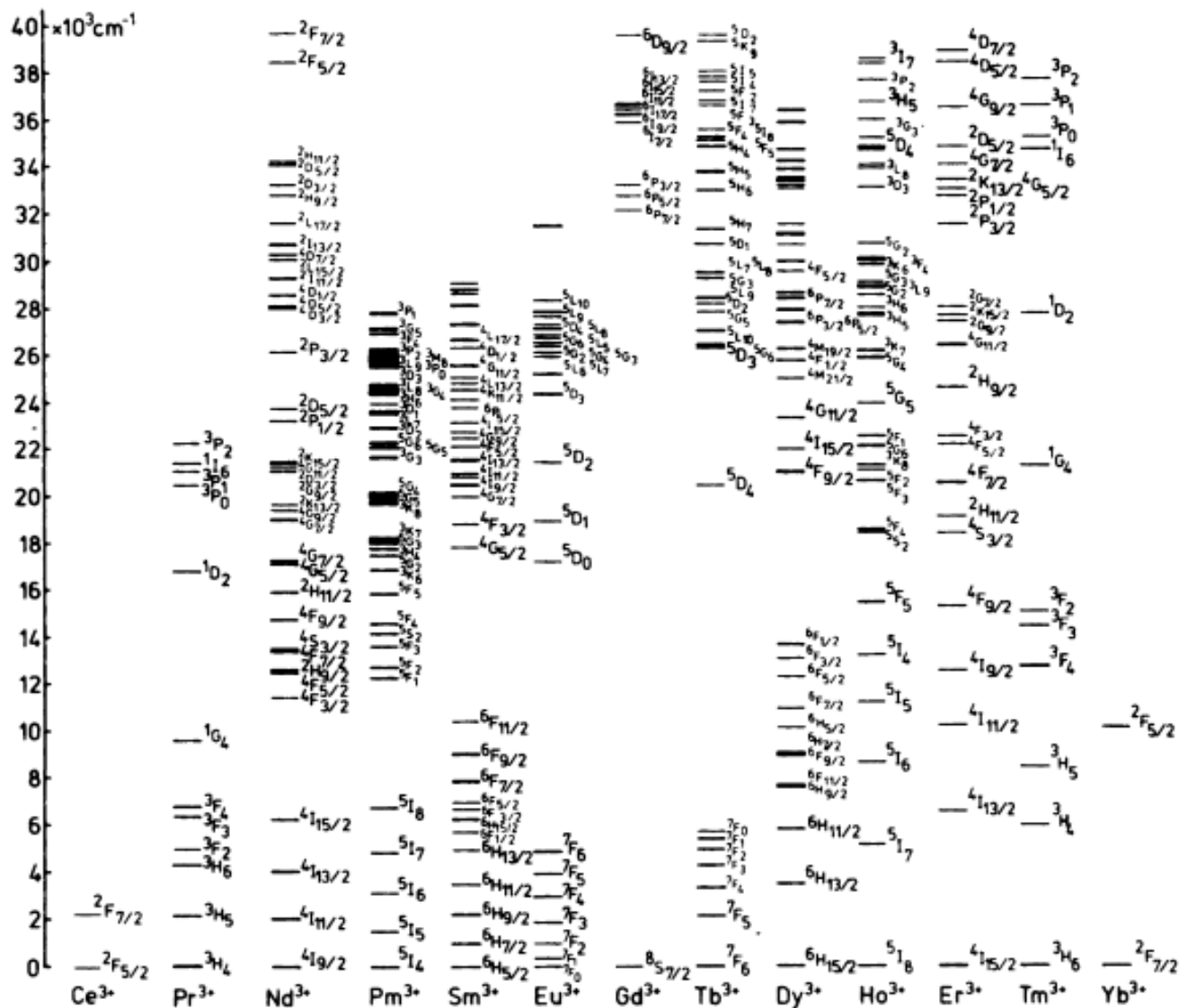➢Vapour pressure: at 1504 K, 10^{-2} mbar;

➢e^- configuration:

$(1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6)\ 4f^{12} 6s^2 \rightarrow {}^3H$

$6s6p \rightarrow 6s^2$

$5d6s \rightarrow 6s^2$

Configuration	Term	J	Level (cm^{-1})
$4f^{12} 6s^2$	^3H	6	0.000
		5	6958.329
		4	10750.982

[National Institute of Standards and Technology]

Hufner, S., Optical spectra of transparent rare earth compounds.
ACADEMIC PRESS New York San Francisco London 1978

Simplified scheme

to compressor

Cold head + valve unit

Evacuated chamber

Isolating copper shields

s-Neon crystal

Nozzle

Transparent windows 4 x 90^0

Neon

Fluorescence → Photo-detector

EM excitation

to the pumping unit