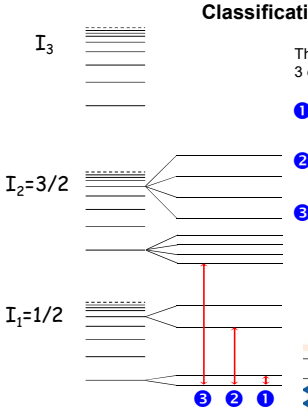
laser spectroscopy

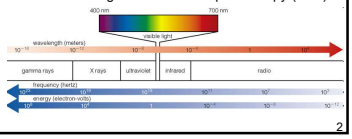
www. hyperfinecourse .org

Classification of nuclear methods



These 3 energy scales distinguish
3 different classes of experimental methods:

1. • Nuclear Magnetic Resonance (NMR)
   • Nuclear Quadrupole Resonance (NQR)
2. • laser spectroscopy
   • Electron Paramagnetic Resonance (EPR)
3. • Low-Temperature Nuclear Orientation (LTNO)
   • NMR on Oriented Nuclei (NMR/ON)
   • forward scattering of synchrotron radiation
   • Mössbauer Spectrocopy (MS)
   • Conversion Electron Mössbauer Spectrocopy (CEMS)
   • Perturbed Angular Correlation spectroscopy (PAC)



2

Laser Spectroscopy

Optics Communications 282 (2009) 562–567

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

High resolution measurements of the hyperfine structure of atomic Lanthanum for energetically low lying levels of odd parity

Günay Başar [a,*], Gönül Başar [b], Sophie Kröger [c]

[a] Technical University of Istanbul, Faculty of Science and Letters, Physics Engineering Department, 34469 Maslak, Istanbul, Turkey
[b] University of Istanbul, Faculty of Science, Physics Department, 34459 Vezneciler, Istanbul, Turkey
[c] Technische Universität Berlin, Institut für Optik und Atomare Physik, Hardenbergstr. 36, 10623 Berlin, Germany

ARTICLE INFO

Article history:
Received 29 July 2008
Received in revised form 24 October 2008
Accepted 26 October 2008

PACS:
32.10.Fn
31.30.Gs
32.30.Jc

Keywords:
Fine and hyperfine structure
Hyperfine interactions and isotope effects
Visible and ultraviolet spectra

ABSTRACT

Doppler-reduced saturation absorption spectroscopy is applied to study the hyperfine structure of excited levels of Lanthanum. 16 transitions in the near infrared wavelength range are investigated. Precise values for the magnetic dipole hyperfine structure constants *A* as well as for the electric quadrupole hyperfine structure constants *B* of the isotope ^{139}La are determined for 14 levels of odd parity and nine levels of even parity. For levels of even parity a good agreement is found with values from previous measurements using sub-Doppler methods. For levels of odd parity previously determined values are improved and for two levels new values of the hyperfine structure constants are reported.

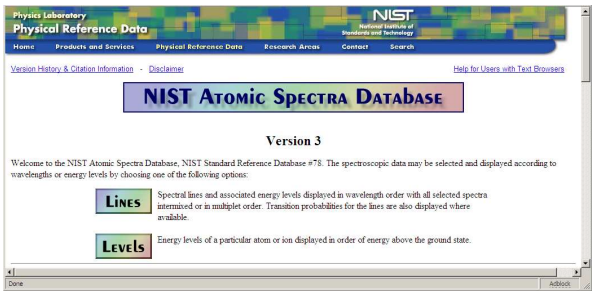
(read the abstract – we are going to try to understand something about it)

3

Laser Spectroscopy

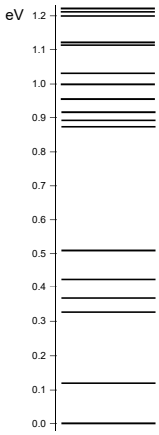
A useful source of info on atomic levels and transitions:

http://physics.nist.gov/PhysRefData/ASD/index.html



4

Atomic energies for La : bare values

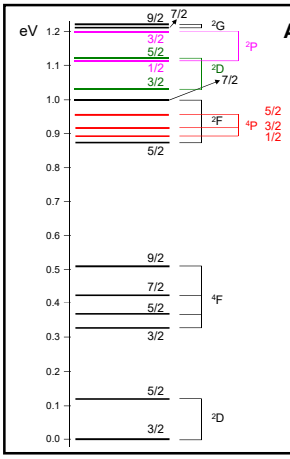


This is a real-life example of our cartoon :

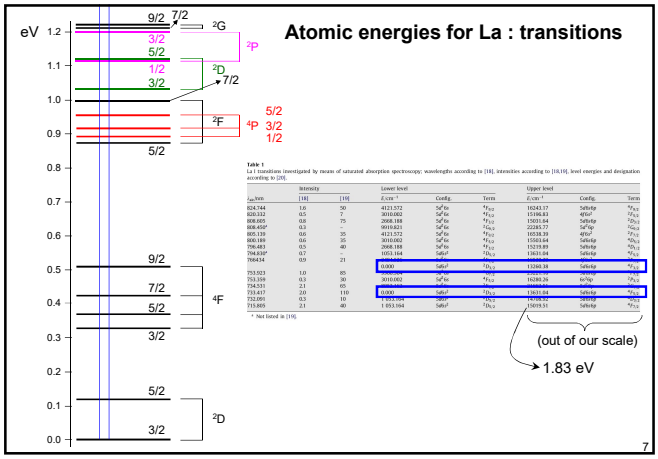
(up to the fine structure, does not yet include hyperfine structure !)

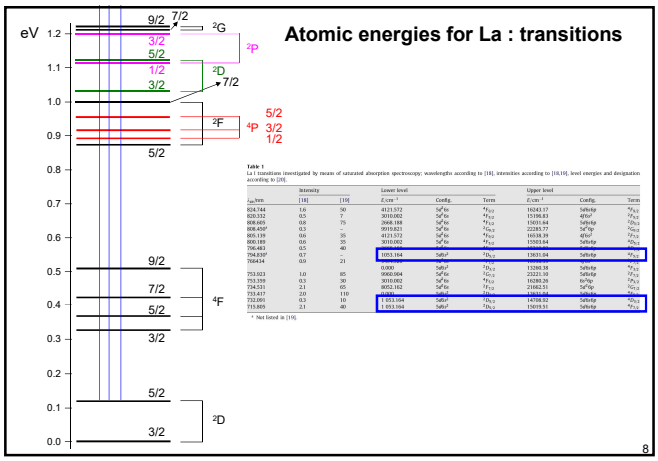
5

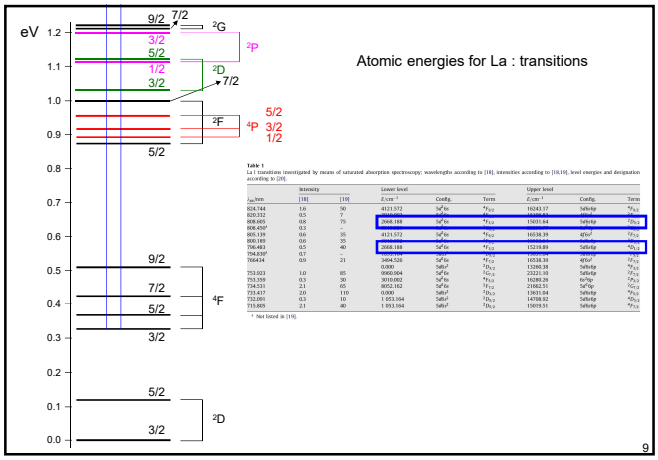
Atomic energies for La : interpreted

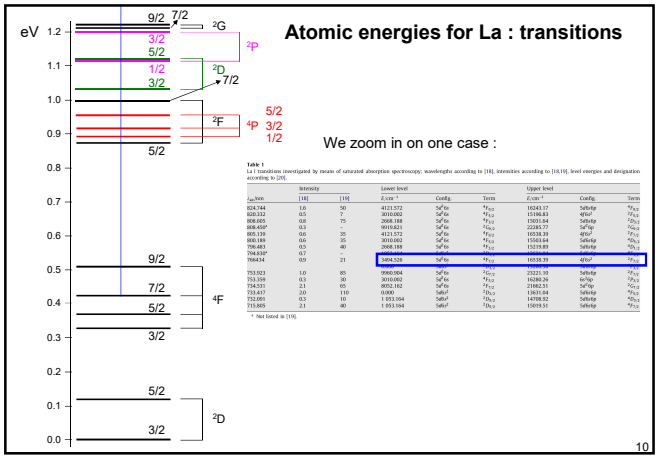


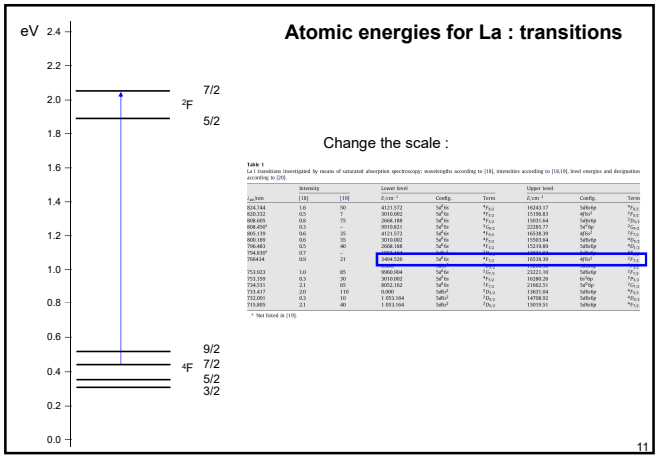
6

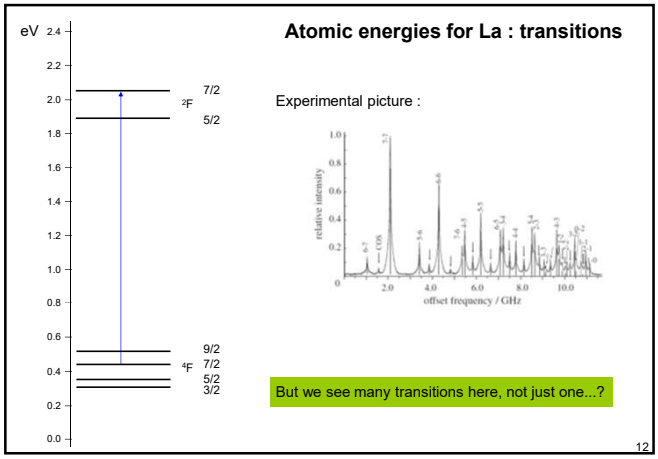

Atomic energies for La : transitions
eV
9/2
7/2
2G
3/2
5/2
2P
1/2
2D
7/2
3/2
5/2
2F
4P
3/2
1/2
5/2
9/2
7/2
4F
5/2
3/2
5/2
2D
3/2
(out of our scale)
1.83 eV
7


Atomic energies for La : transitions
eV
9/2
7/2
2G
3/2
5/2
2P
1/2
2D
7/2
3/2
5/2
2F
4P
3/2
1/2
5/2
9/2
7/2
4F
5/2
3/2
5/2
2D
3/2
8

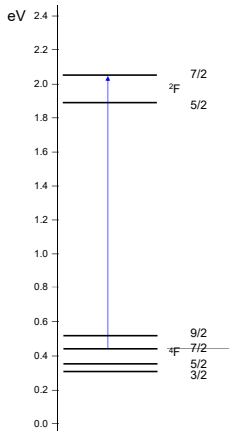

Atomic energies for La : transitions
eV
9/2
7/2
2G
3/2
5/2
2P
1/2
2D
7/2
3/2
5/2
2F
4P
3/2
1/2
5/2
9/2
7/2
4F
5/2
3/2
5/2
2D
3/2
9


Atomic energies for La : transitions
eV
9/2
7/2
3/2
5/2
1/2
3/2
5/2
9/2
7/2
5/2
3/2
5/2
3/2
2G
2P
2D
7/2
2F
5/2
4P 3/2
1/2
4F
2D
We zoom in on one case :
10


Atomic energies for La : transitions
eV
7/2
2F
5/2
9/2
4F
7/2
5/2
3/2
Change the scale :
11


Atomic energies for La : transitions
eV
7/2
2F
5/2
9/2
4F
7/2
5/2
3/2
Experimental picture :
relative intensity
offset frequency / GHz
But we see many transitions here, not just one...?
12

Atomic energies for La : transitions

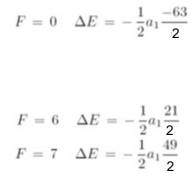


This is ^{139}La, and this nucleus has I=7/2

F = I+J, ... , |I-J|

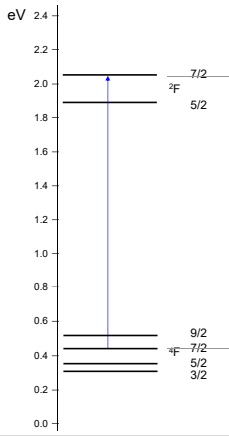
For this transition: J=7/2, for lower and upper level.

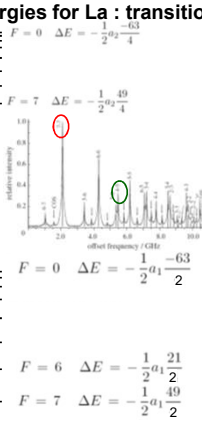
Hence, F = 7, 6, 5, 4, 3, 2, 1, 0



13

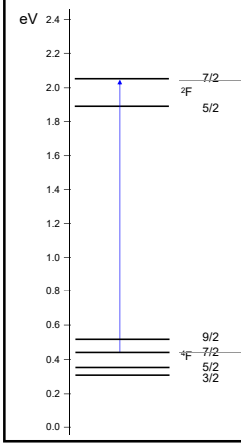
Atomic energies for La : transitions

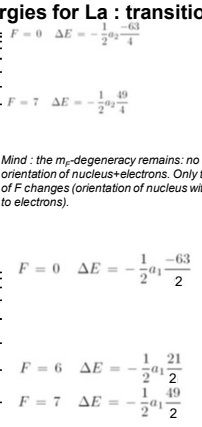




14

Atomic energies for La : transitions





Mind : the m_F-degeneracy remains: no absolute orientation of nucleus+electrons. Only the value of F changes (orientation of nucleus with respect to electrons).

15

Laser spectroscopy : results

By measuring these transitions, the hyperfine splitting (magnetic+electric) in the lower and upper levels of the transition can be determined :

Table 2
Experimental hyperfine structure constants A and B of La I for the levels of even parity from this work and from [2,3,6,8–10,14,15]. Energies, configurations and terms are given following [20]. ablif: atomic beam laser-induced fluorescence, ftx: Fourier transform spectroscopy, ogs: optogalvanic spectroscopy, lirf: laser-induced resonance fluorescence, abmr: atomic beam magnetic resonance. In column six for all levels investigated in this work, the wavelength of the investigated transitions are given, instead of the method (which is in all cases saturated absorption spectroscopy).

E/cm^{-1}	Config.	Term	A/MHz	B/MHz	Method/wavelength/nm	Refs.
0.000	$5d6s^2$	$^2D_{3/2}$	141.3(2)	45(3)	753.923	This work
			140.9(8)	49(5)	733.417	This work
			141.1959(16)	44.781(14)	abmr	[2]
			147(6)	–	ogs	[9]
			141.60(42)	44.04(85)	ablif	[15]
1053.164	$5d6s^2$	$^2D_{5/2}$	182.3(2)	55(2)	794.830	This work
			182.6(5)	54(4)	732.091	This work
			182.5(0.4)	55(4)	715.805	This work
			182.1706(6)	54.213(14)	abmr	[2]
			210(5)	–	ogs	[9]
			183(5)	–	ogs	[10]

hyperfine structure constant A (a.k.a. “a”, see week 4)

$$a = \frac{\mu B_J}{IJ}$$

nuclear electric quadrupole coupling constant (NQCC) : eQV_{zz}/h

16