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Laser polarization of ^{23}Mg

International MORA workshop May 2nd to 5th 2022

Laser spectroscopy: measurements of atomic structure to infer nuclear structure

- Hyperfine interaction: interaction between nuclear moments and bound electrons

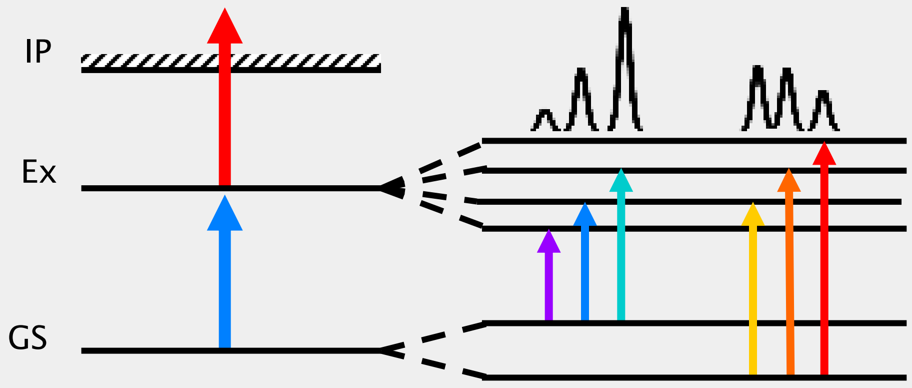
$$h\nu \sim \nu_0 + A\frac{C}{2} + B\frac{1}{4}\frac{(3/2)C(C+1) - 2I(I+1)J(J+1)}{I(2I-1)J(2J-1)}$$

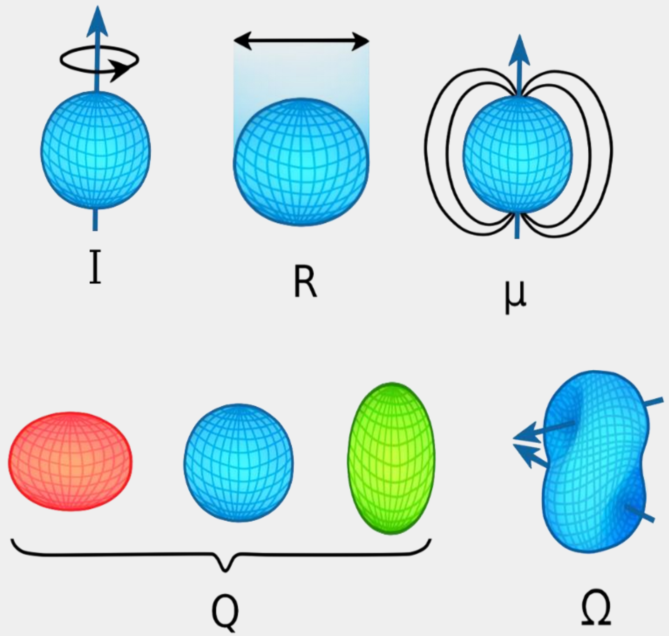
- Model-independent extraction of:

$\delta\langle r^2\rangle$ $A = \frac{\mu_I B_J}{IJ}$ $B = eQV_{zz}$

provided the atomic parameters are known (e.g. knowing mass and field shift is required)

- Electromagnetic moments teach us about nuclear configurations, sizes and shapes
- Good tests of nuclear theory



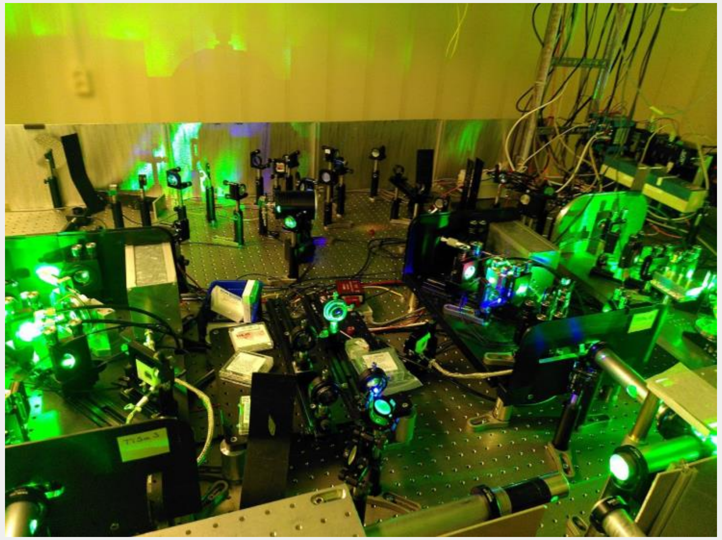


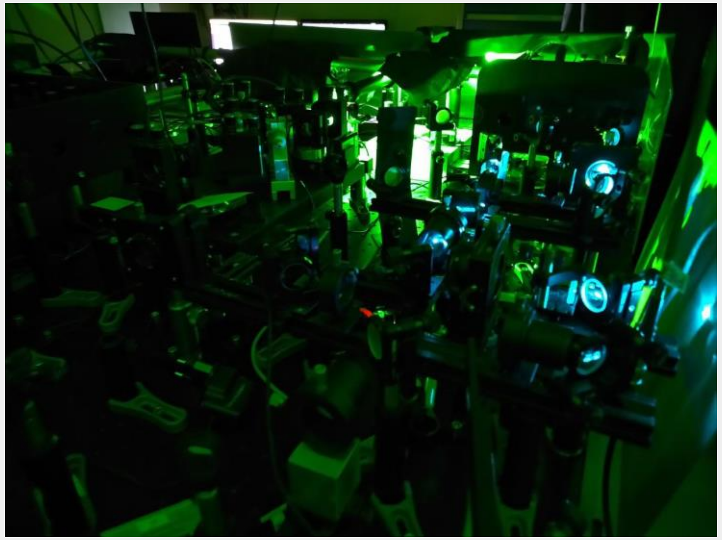
Lasers at IGISOL

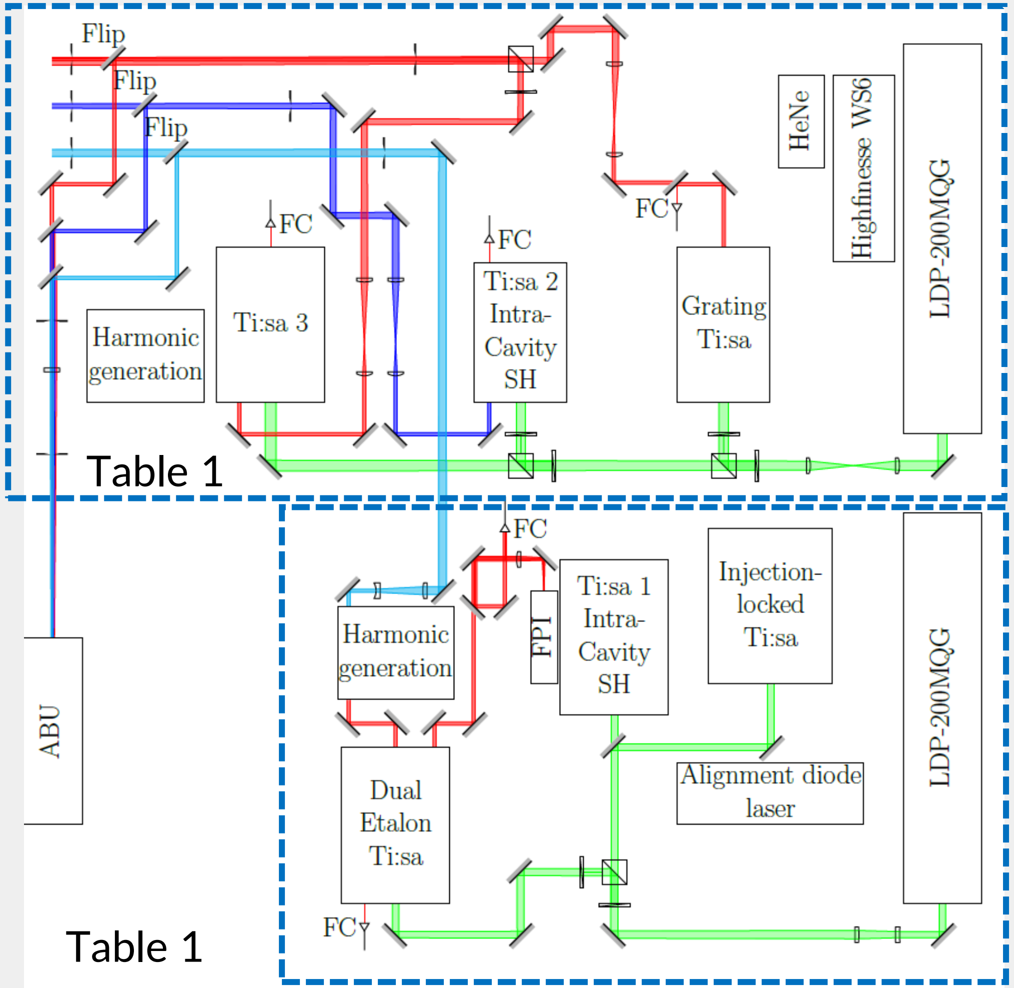
A 10 kHz repetition rate solid state laser system:

- tuning range:
  - Fund.: 680 - 1050 nm
  - 2nd.: 340 - 525 nm
  - 3rd: 230 - 350 nm
  - 4th: 205 - 260 nm

- laser linewidth per application:
  - In-gas cell >5 GHz
    - Single etalon
  - Hot cavity ~1 GHz
    - Dual etalon
  - In flight <100 MHz
    - Injection-locking



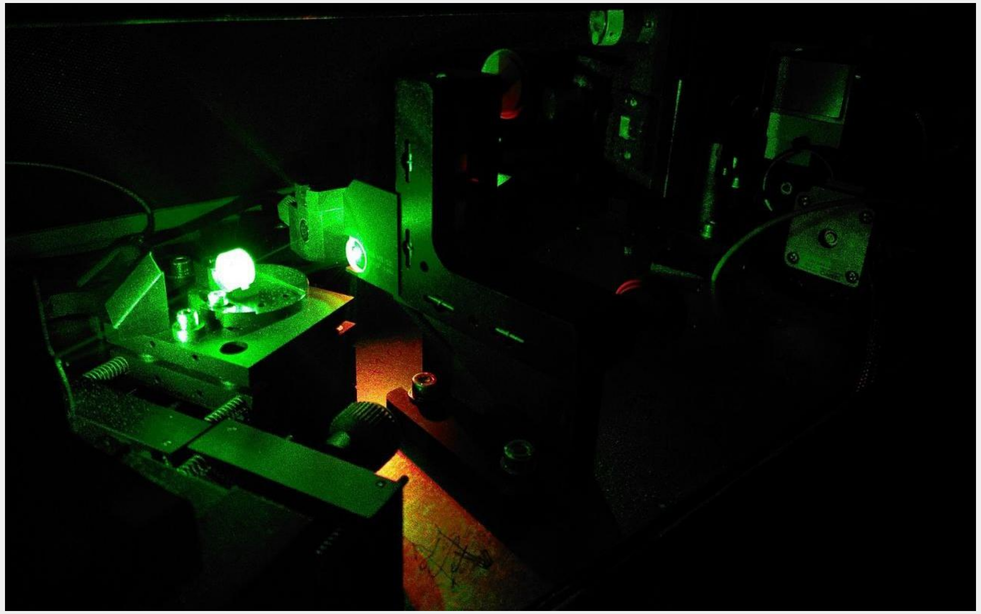


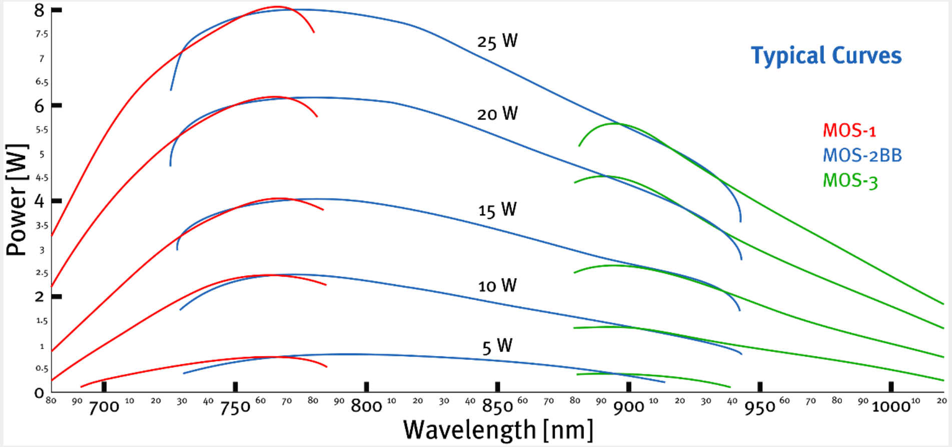


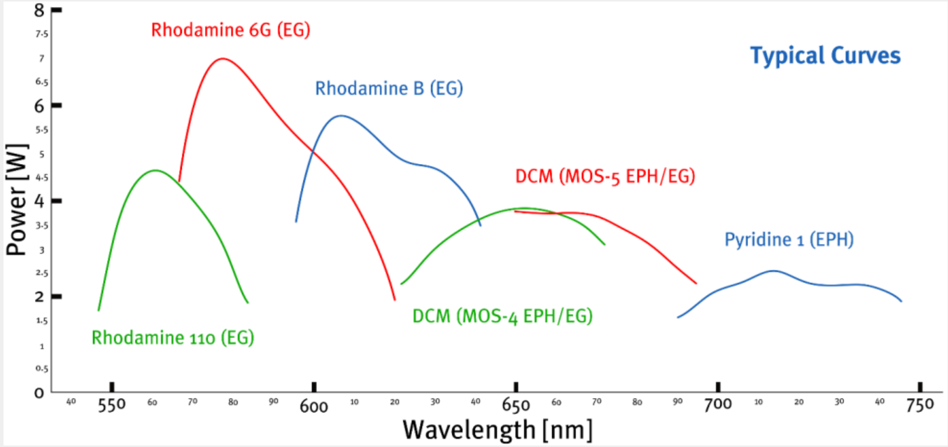
M. Reponen, I.D. Moore et al., Eur. Phys. J. A 48 (2012) 1

Lasers at IGISOL

- Single-mode Dye/Solid state continuous wave laser system:
  - Matisse titanium-sapphire and dye laser to cover ~550 – 1000 nm and higher harmonics
  - Bandwidth < 1 MHz

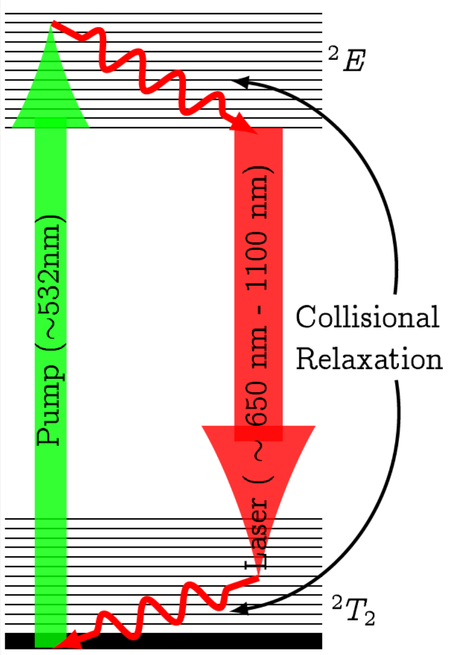






Titanium:sapphire laser

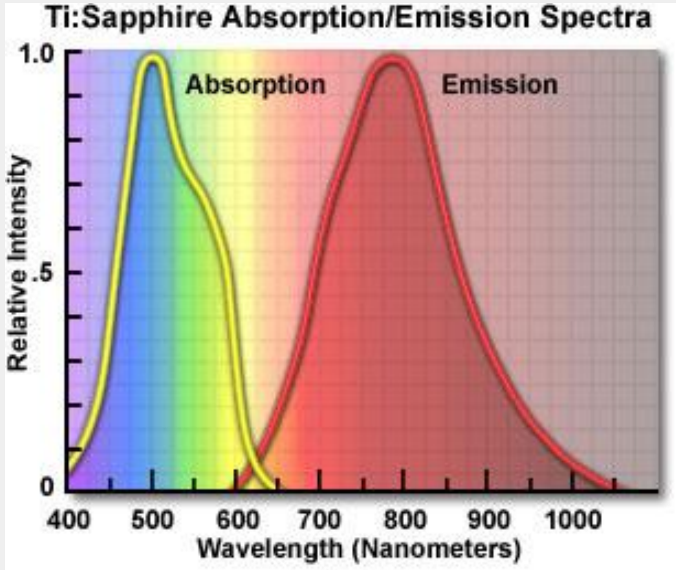
- Lasing medium:
  - optically active Ti^{3+}, <1% weight
  - in host solid sapphire, Al_2O_3
  - Gain bandwidth >100 THz (400 nm)

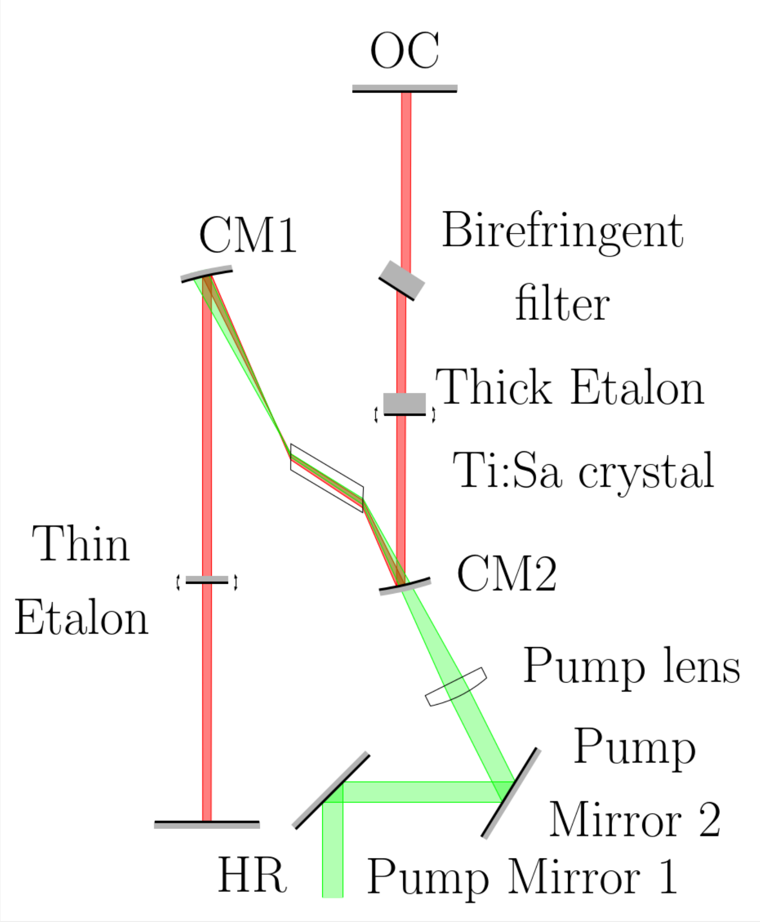


Fast decay

Lasing

Fast decay

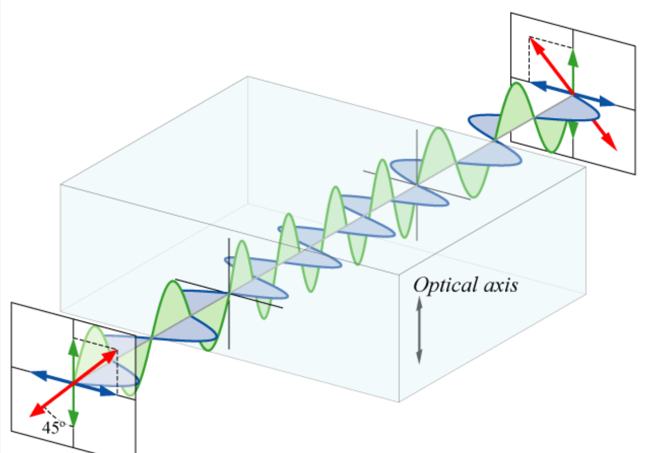


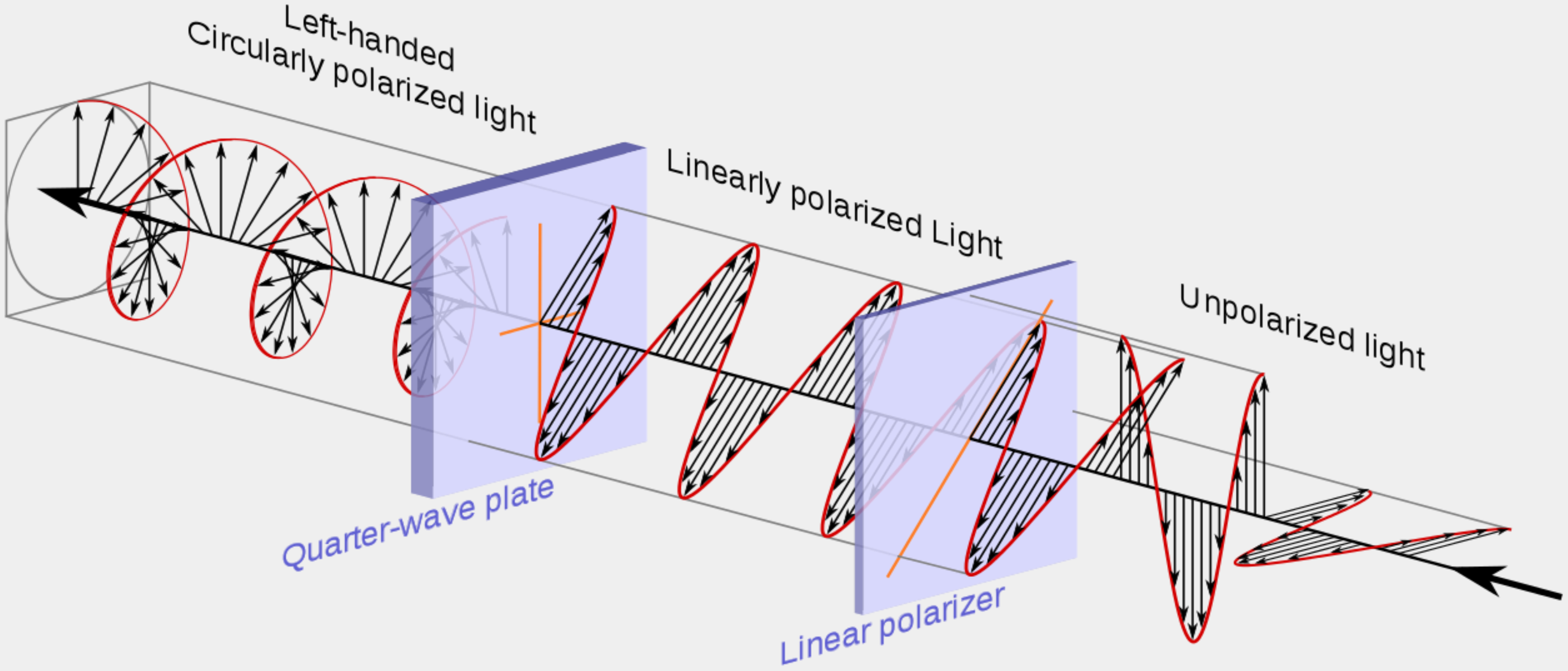


Z-shaped TISA resonator with a dual etalon arrangement.

Polarization of light

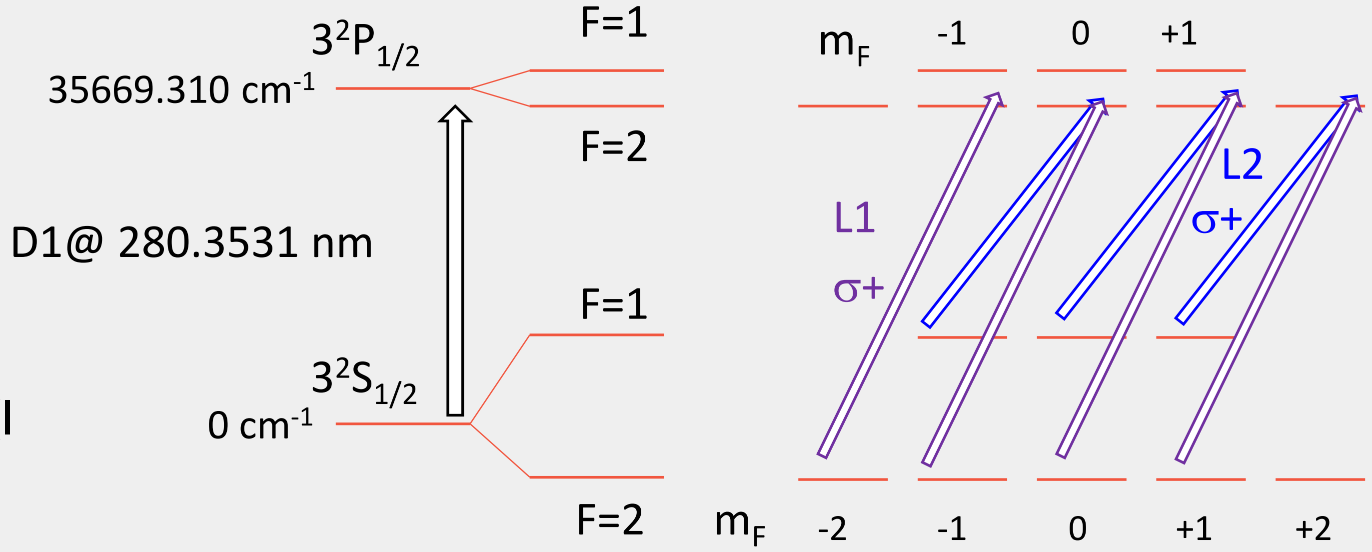
- Property applying to transverse waves
  - Linear or elliptical polarization
    - Circular a special case
- Can be manipulated with waveplates (optical retarders)
  - Material with birefringence





Laser polarization of Mg

- Hyperfine levels F=I+J have magnetic substates m_F
  - Circularly polarized light: change of m_F = +1 (-1) for σ+(σ-)
  - Spontaneous decay: Δm_F = 0,+/-1
- Optical pumping schemes to polarize Mg (I = 3/2+) ions are well established.
- L1 and L2 are circularly-polarized laser radiation, shifted by 1460 MHz.
  - Both F=1 and F=2 ground state HF levels can be accessed with BB laser.

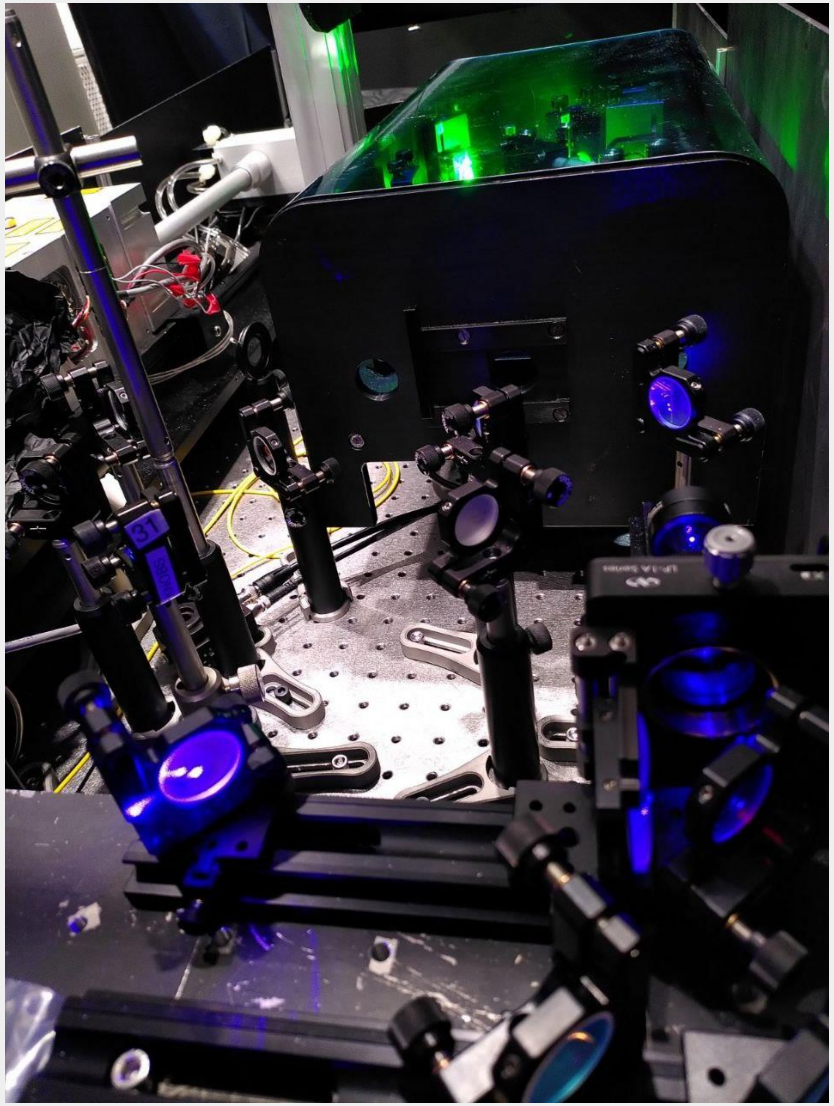


ΔF = 0, ±1; Δm_F = 0, ±1 (spontaneous emission)
Pumping to stretched (F=2, m_F = ±2)state leads to maximal nuclear polarisation

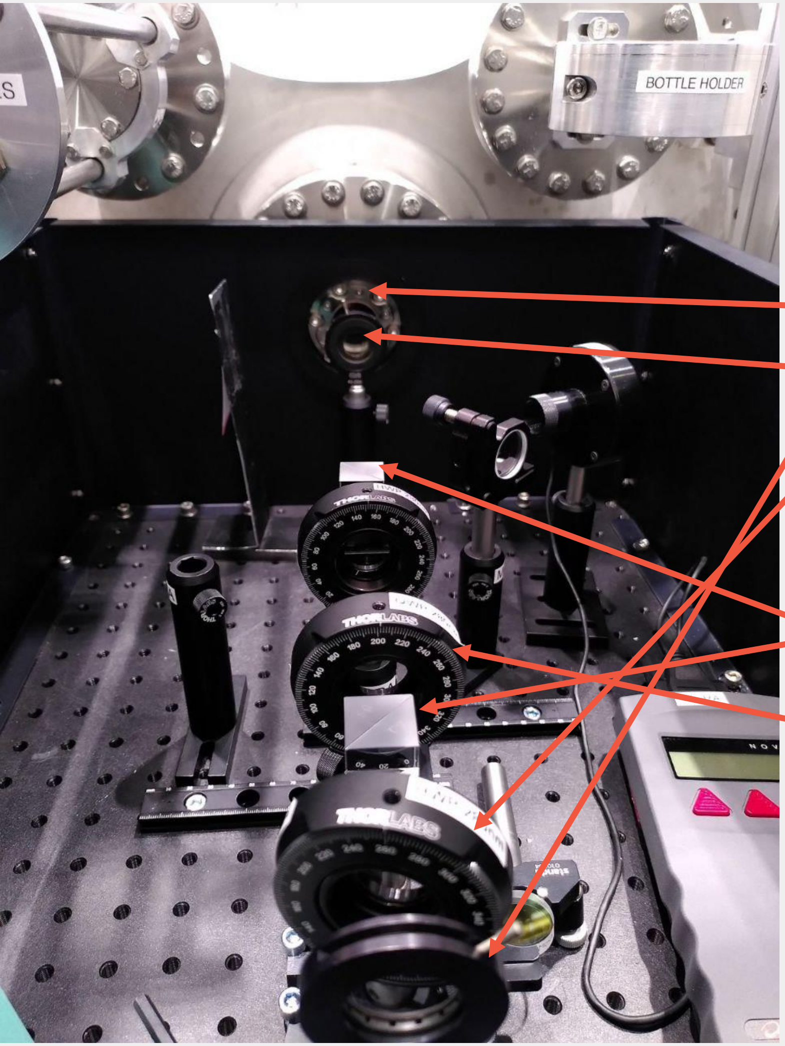
σ^+: ΔF = 0, ±1; Δm_F = +1
σ^-: ΔF = 0, ±1; Δm_F = -1

MORA laser polarization setup at IGISOL

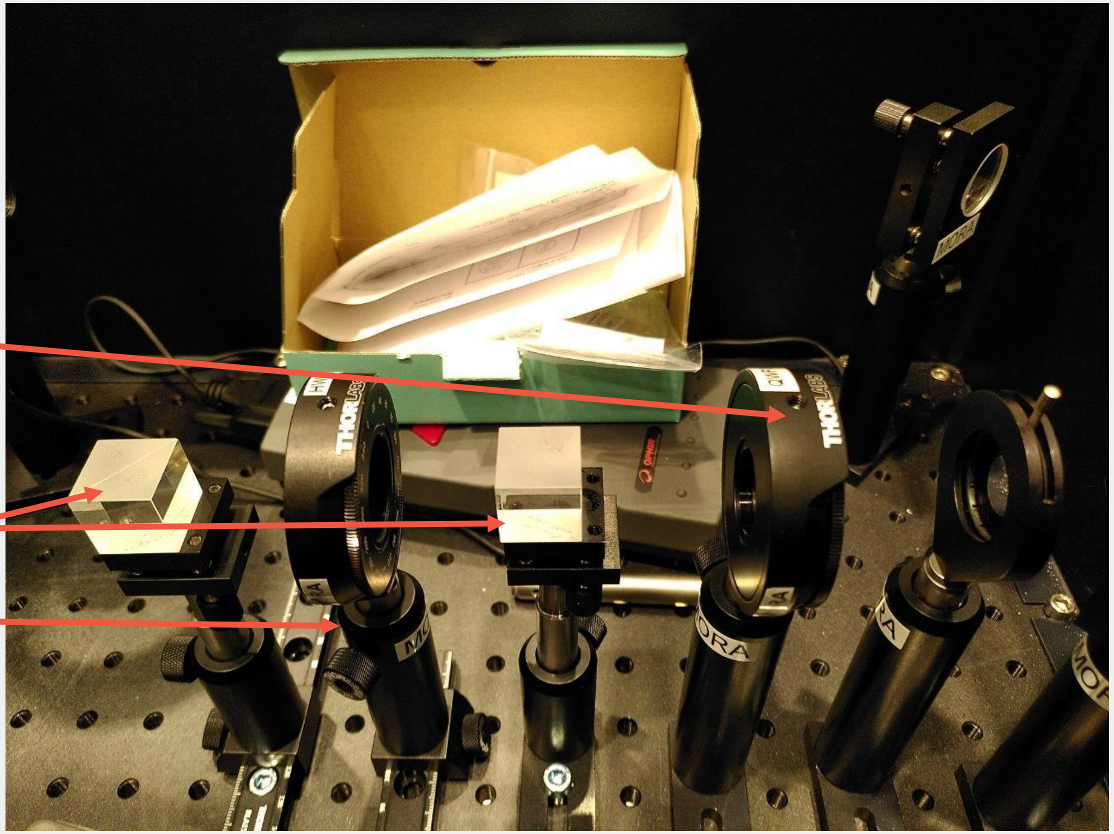
- Shares laser infrastructure with RAPTOR.
  - 25 W, 10 kHz Nd:YAG pump laser
  - Single standard Ti:sapphire amplifier
  - Harmonic generation stage
    - Optimized atm. For 280 nm range
      - Mg, Sn, Cu, Pd… first steps
  - Laser path for MORA and for RAPTOR
    - Lasers from FURIOS can be transported to the bench.
- Used recently for Mg for MORA and RIS of Cu in Raptor
  - E.g. About 100 mW for Mg pumping.



MORA laser polarization setup at IGISOL



- MORA viewport
- Iris
- Quarter-wave plate
- Polarizing cube
- Half-wave plate



Changing of circular polarization handedness

- Birefringence of crystals can modify the polarization of light
  - Half-wave plate changea left-hand circularly polarized light into right-hand circularly polarized light.
    - Wavelength dependence
- Other options:
  - Normal reflection from a mirror
    - Changes direction
  - Double Fresnel rhomb
    - Optical beam displacement

Slide Acknowledgements

Ruben de Groote, Iain D. Moore