Construction of Lithium Photoassociation Laser

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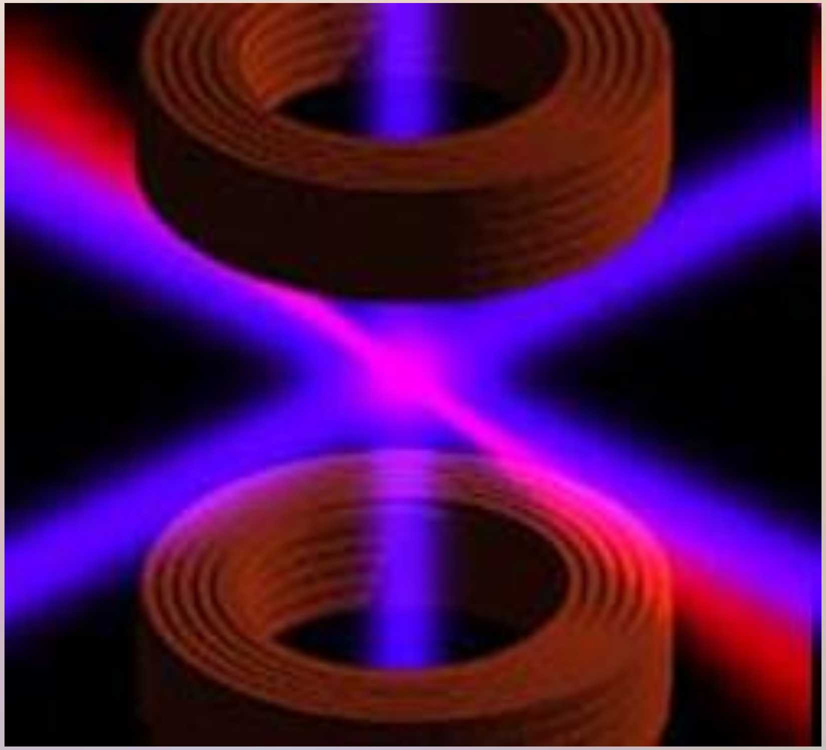
Atomic Physics



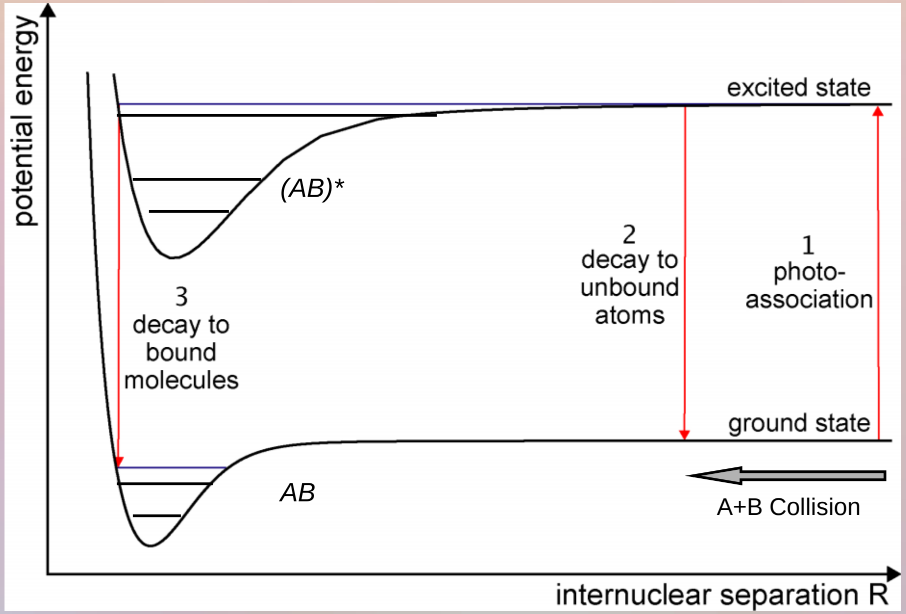
[1]

- Interaction of matter with light
  - Laser systems ubiquitous
- Experimental techniques include:
  - Laser cooling
  - Optical trapping
  - Photoassociation
- Spectacular Results:
  - Advanced Spectroscopy
  - Exotic States of Matter
  - Molecular Synthesis

What is Photoassociation?

- Two colliding atoms absorb a photon to form an excited molecule:

$$A + B + \gamma \rightarrow (AB)^*$$



[2]

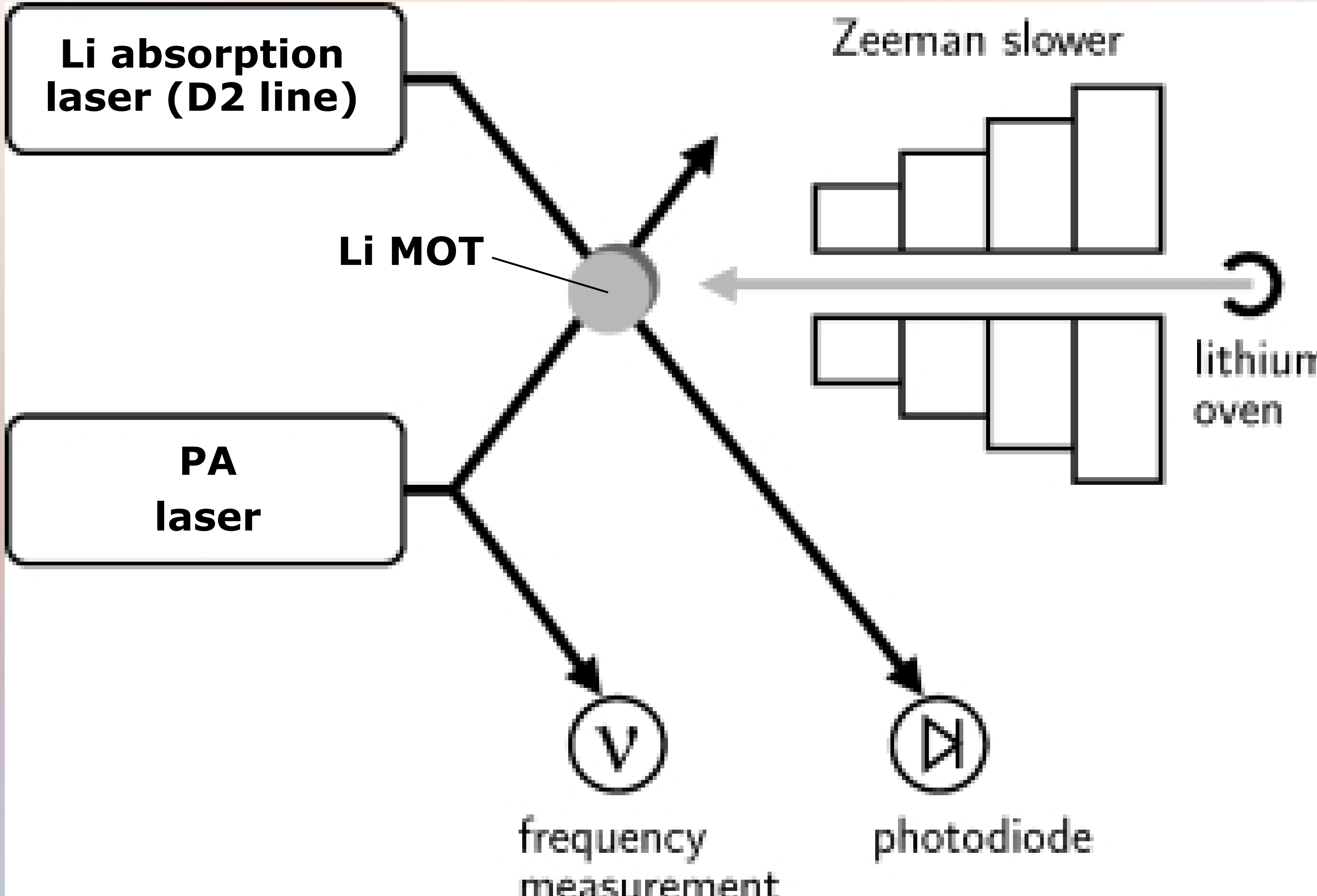
- Theory accounts for long & short range atomic interactions (van der Waals and Born-Oppenheimer potentials, Hund's cases, scattering properties, etc.) in modeling molecular potentials; Alkali metals ideal

Photoassociation (PA) Spectroscopy

One-photon PA spectroscopy resolves excited molecular energy levels

Two-photon PA spectroscopy resolves ground-state molecular energy levels

- Experimental Conditions:
  - Atoms should be slowed, cooled, and confined
  - Minimize kinetic energy spread within atom sample (ultra-cold environment)
  - Narrow-linewidth, tunable PA light source
- Experimental Setup:
  - Atoms initially slowed and cooled through Zeeman slower (‘optical molasses’)
  - Atoms confined within magneto-optical trap (MOT)
  - PA transitions driven by external-cavity diode laser (ECDL) assembly


Li absorption laser (D2 line)
Zeeman slower
Li MOT
lithium oven
PA laser
frequency measurement
photodiode

[3]

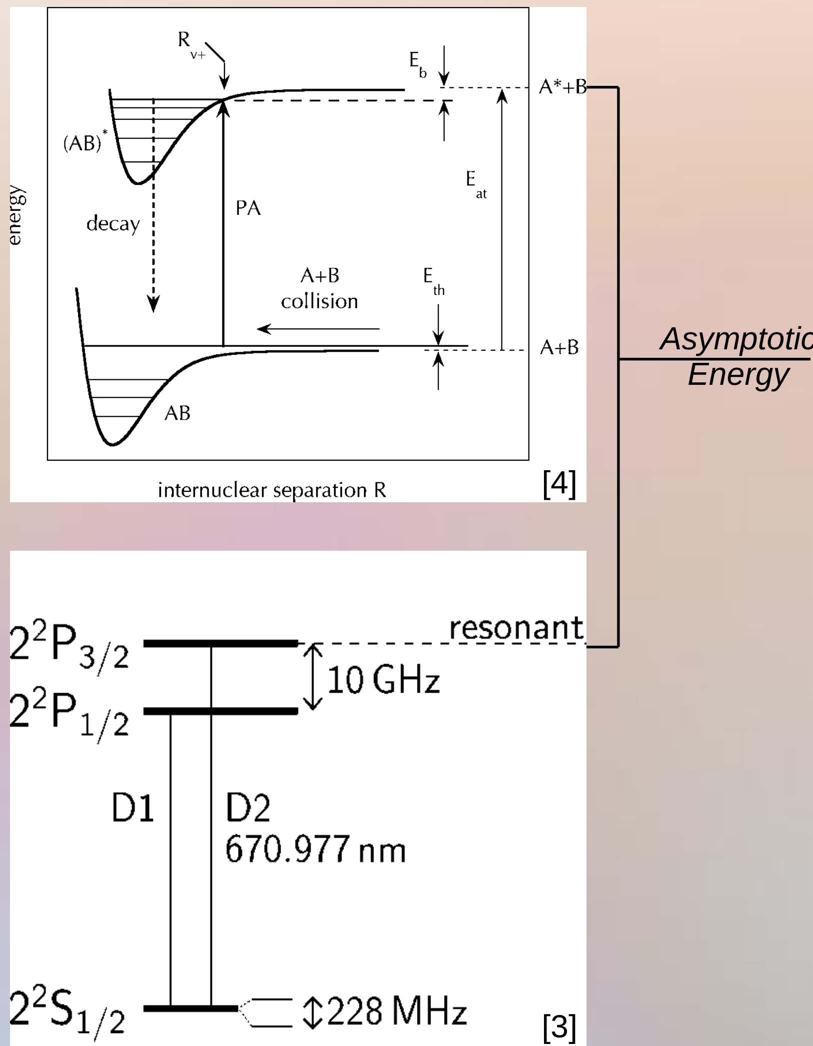
PA Spectroscopy (Cont.)

- Method
  - PA features two characteristic decay processes:

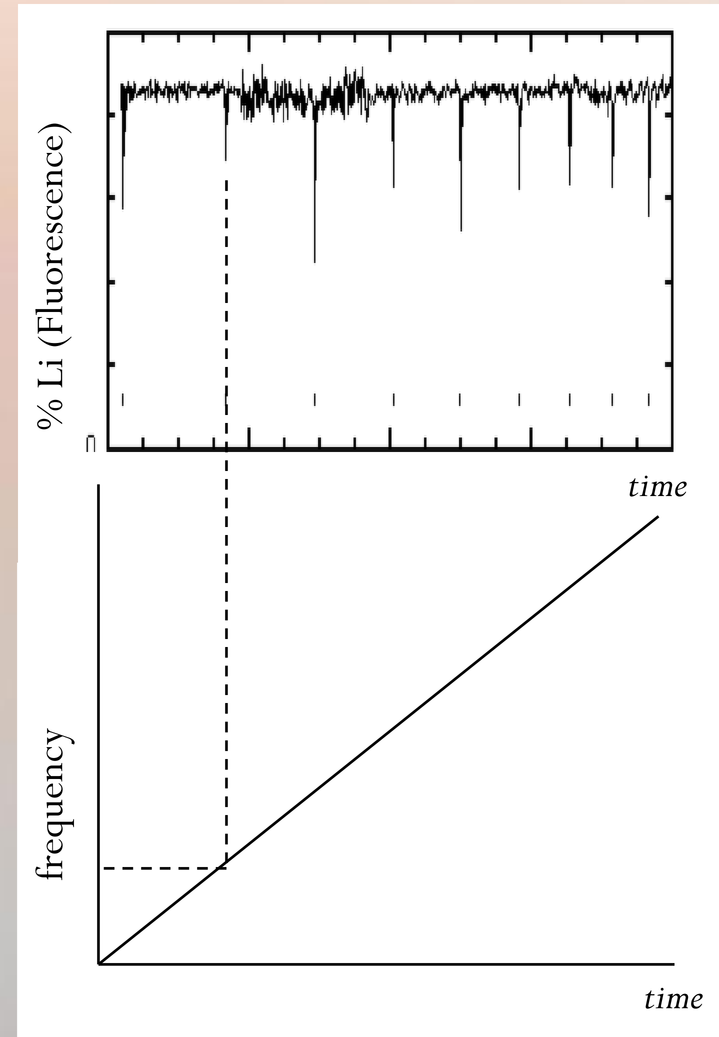
$$(AB)^* \rightarrow A + B + \gamma_{decay} \quad or \quad (AB)^* \rightarrow AB + \gamma_{decay}$$

  - Most simply, PA spectrum measures number of molecules produced
  - In *one-photon* PA experiments, count product molecules by *trap loss* method; both decay processes cause atoms to escape MOT
  - Can detect trap loss by monitoring fluorescence intensity of MOT. We observe a decrease in fluorescence intensity at resonant frequencies.
  - Narrow-linewidth laser source critical for accurate spectroscopy

PA Spectroscopy in Gupta Lab



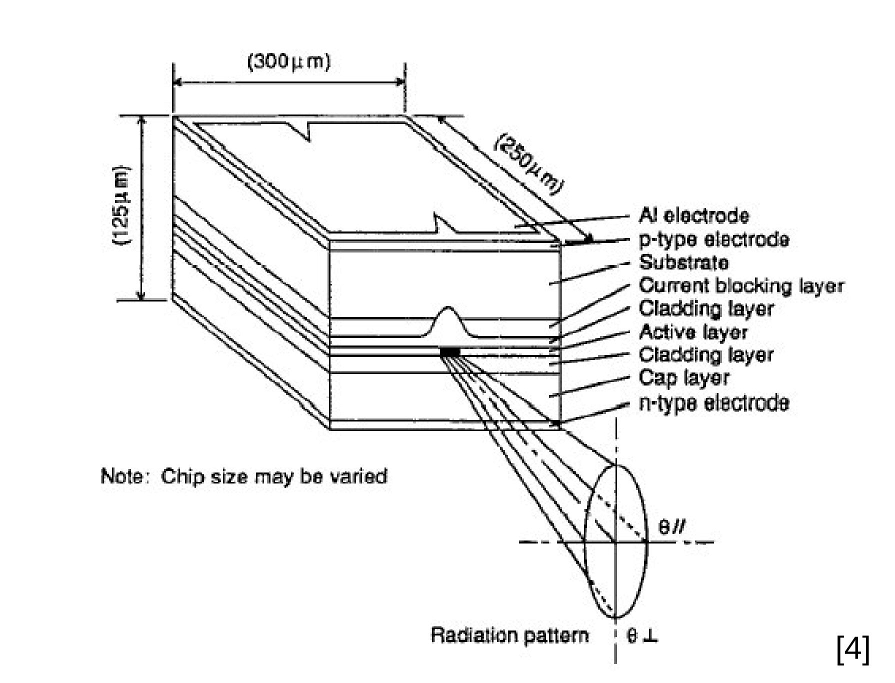
PA laser scanned 'just red' of Li D2 transition



Correlate intensity and frequency scans in time

Lithium Photoassociation Laser

- ECDL setup ideal
  - Narrow linewidth and excellent tunability
  - Diodes centered at 670-671nm readily available; Eagleyard Photonics ridge waveguide laser diode
  - Diffraction grating and collimating optics mounted in Littrow configuration to provide diode with optical feedback



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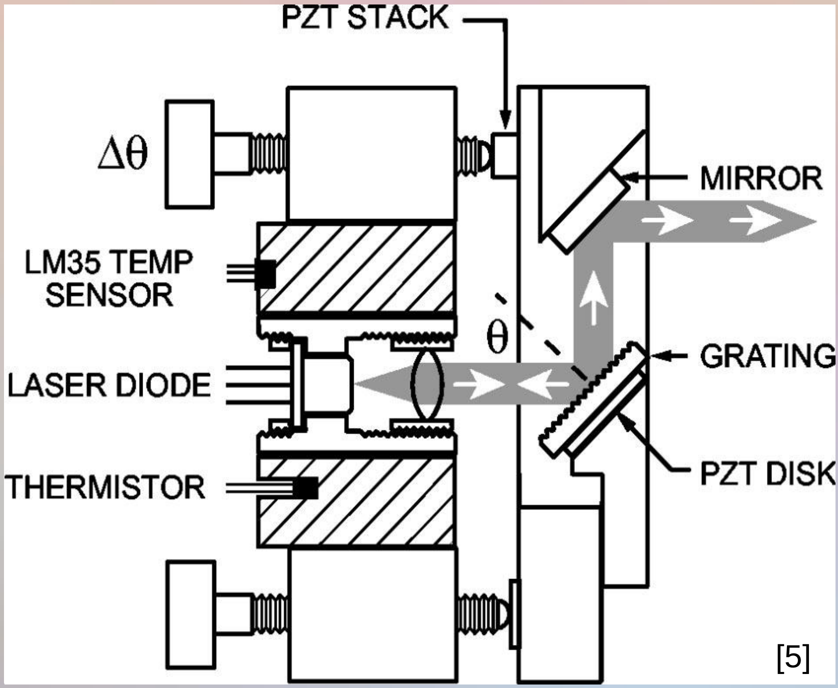

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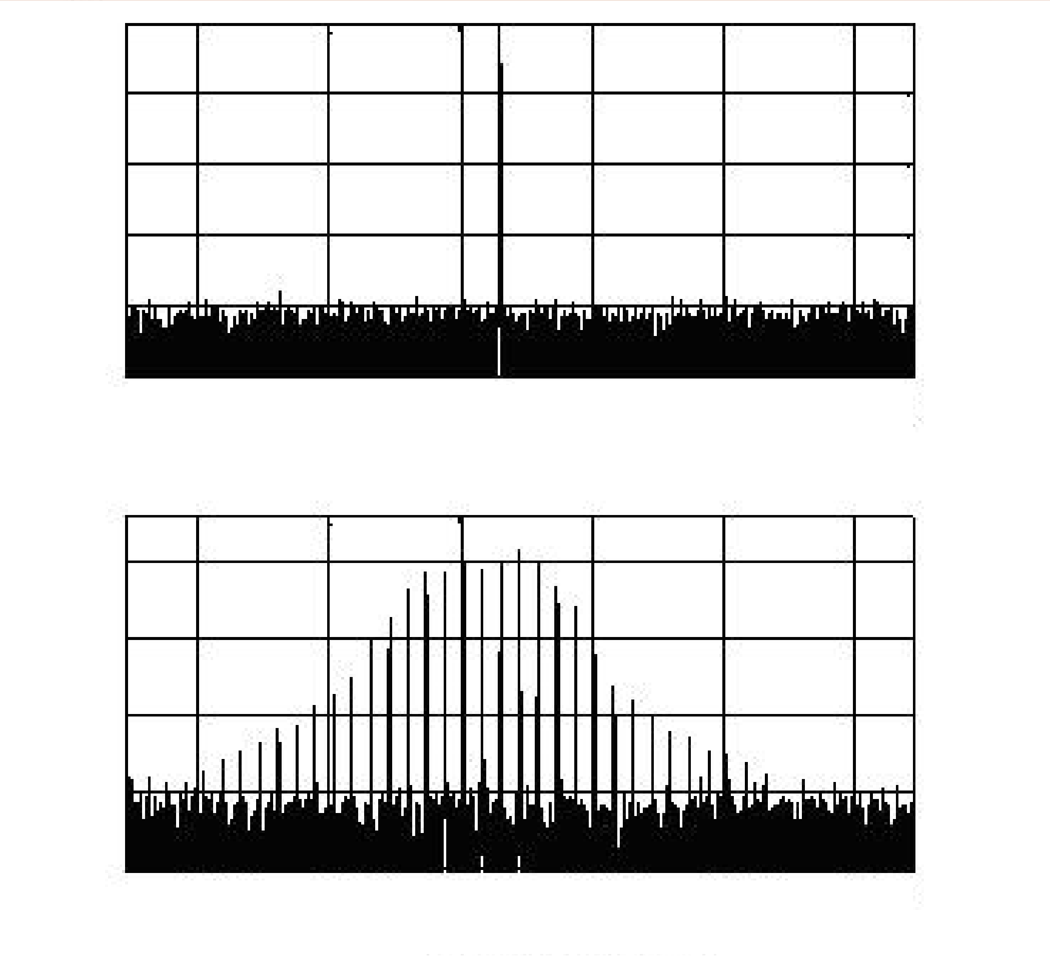
Lithium Photoassociation Laser

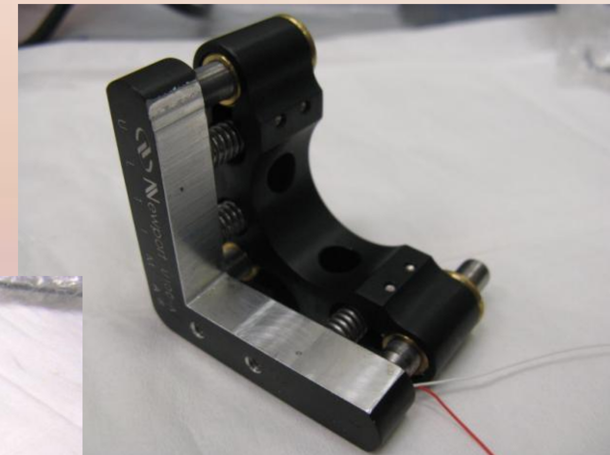
Effects of optical feedback at diode ‘seed point’ – Fabry-Perot spectrum:



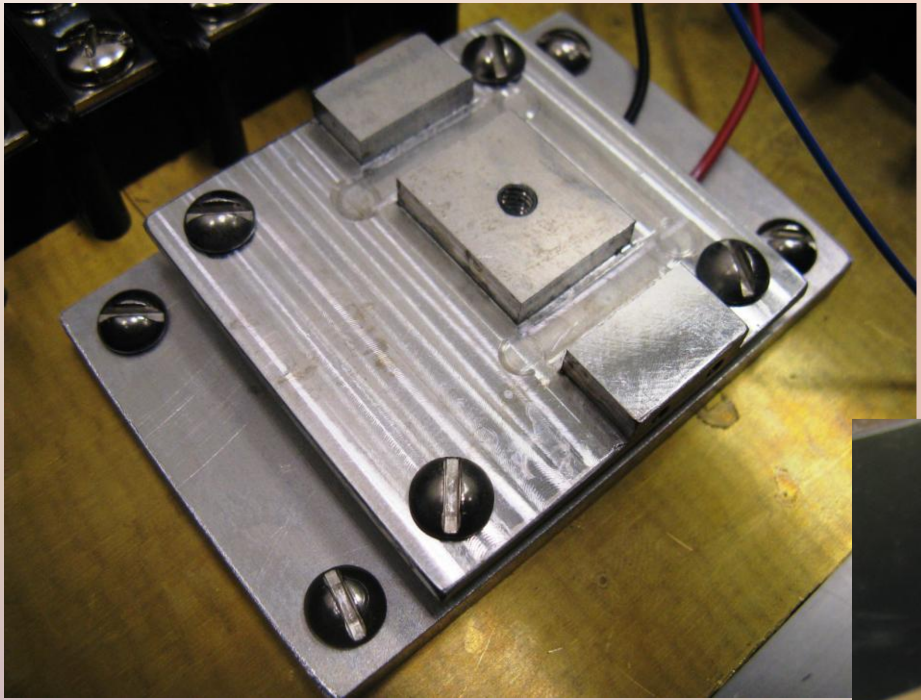
One Mode Isolated

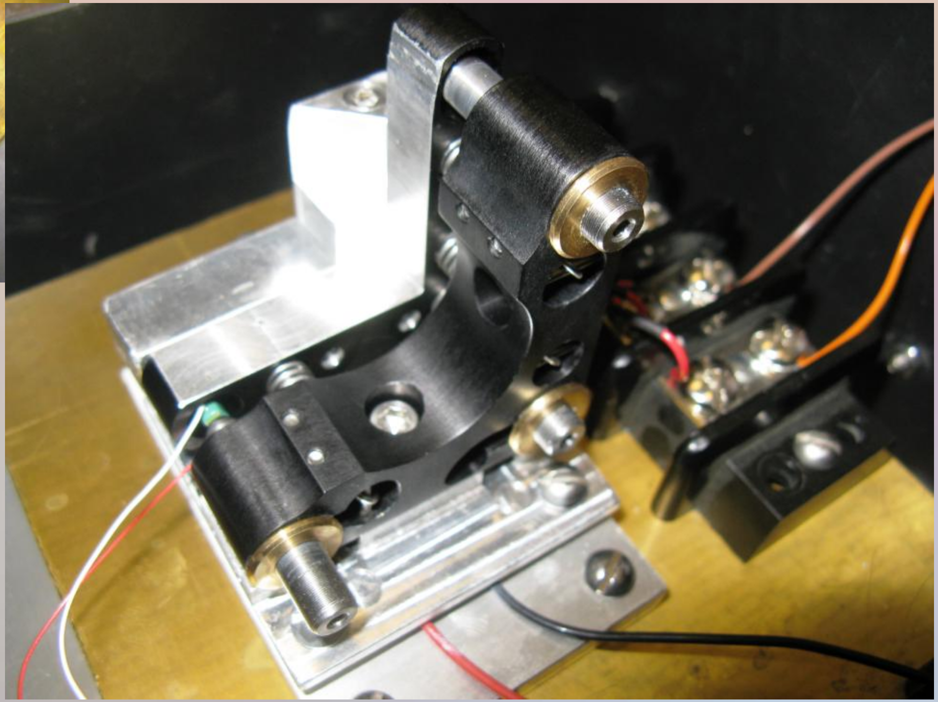
Mode Hopping

Laser Construction Photos

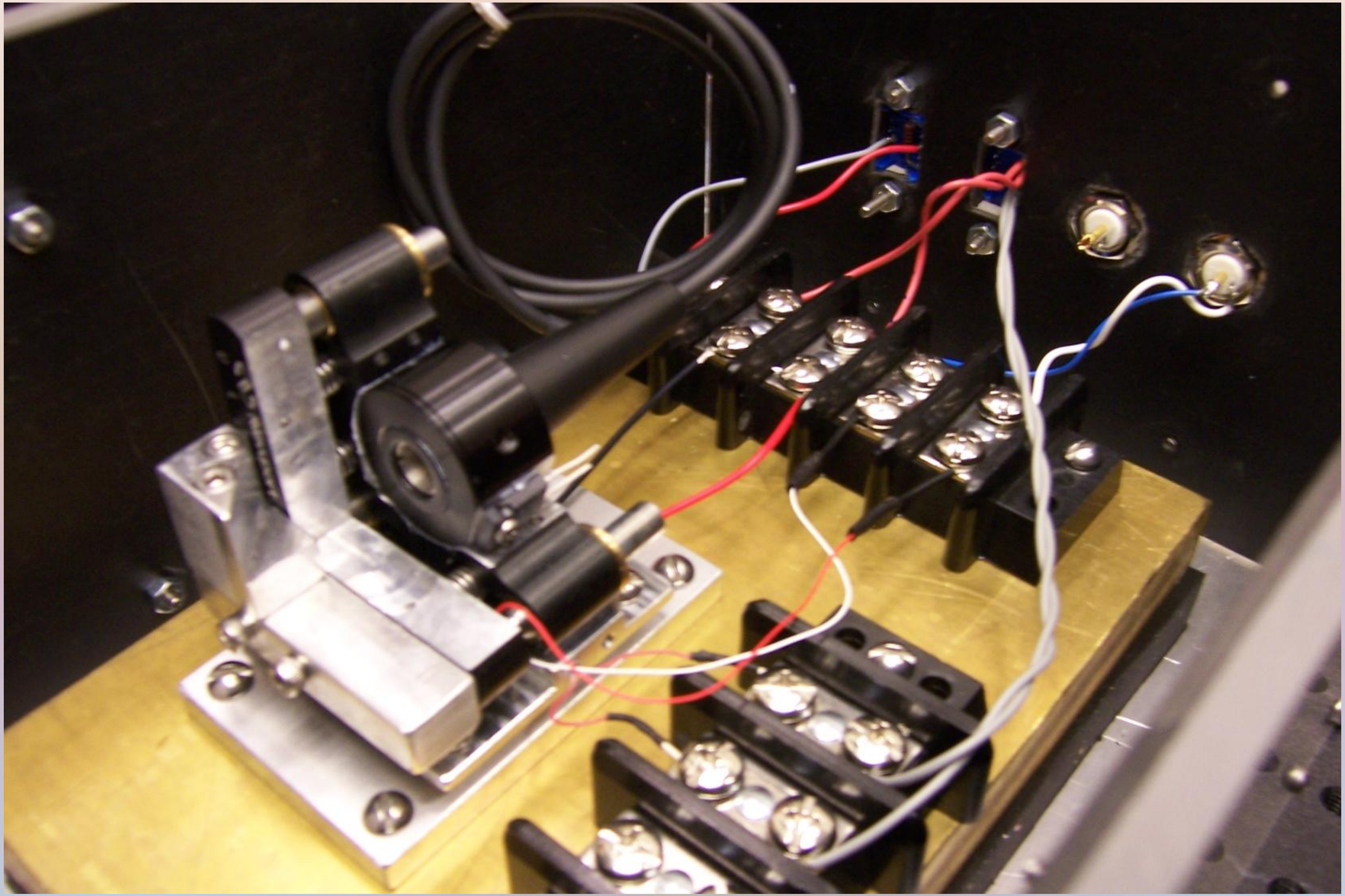


Laser Construction (cont.

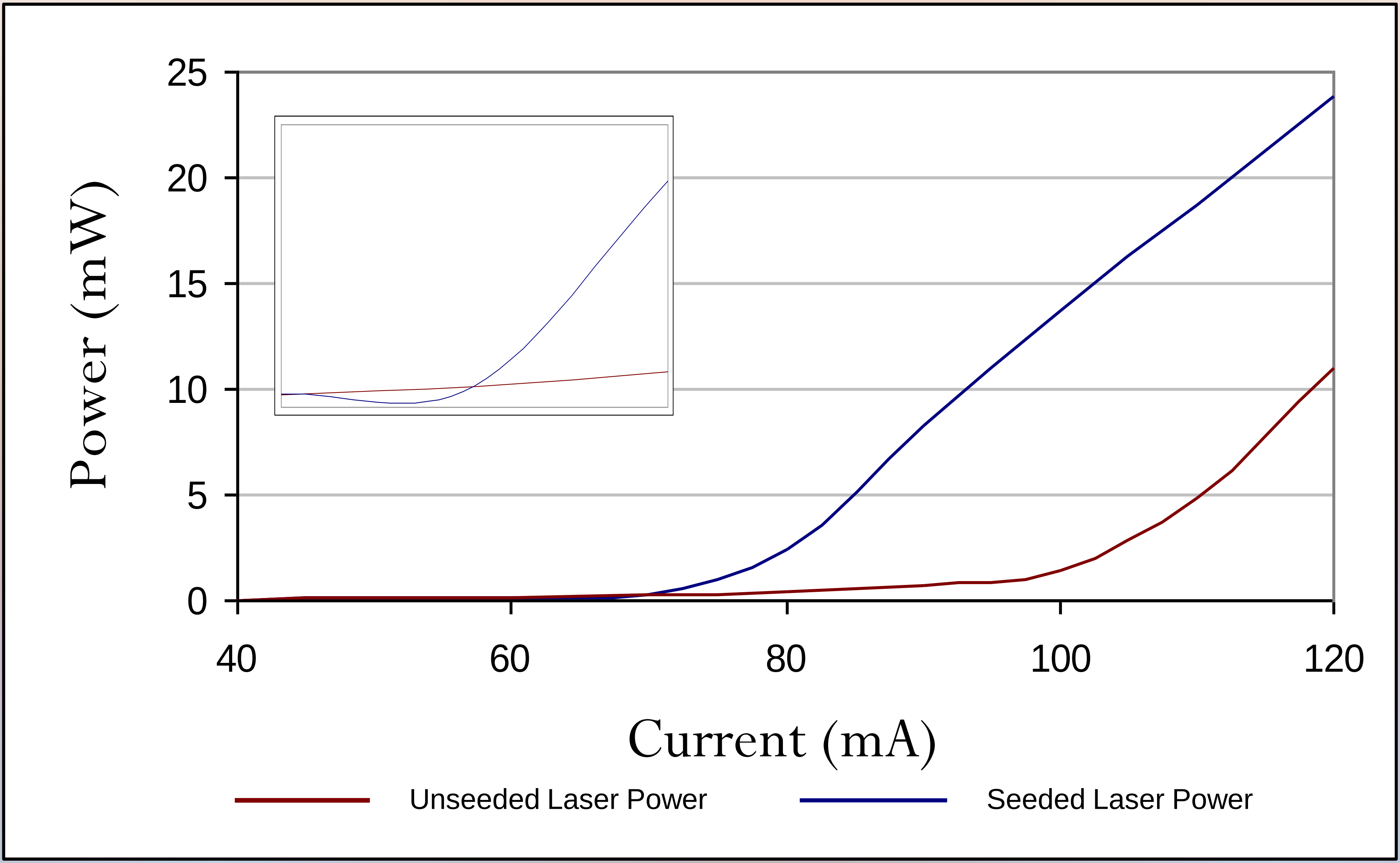




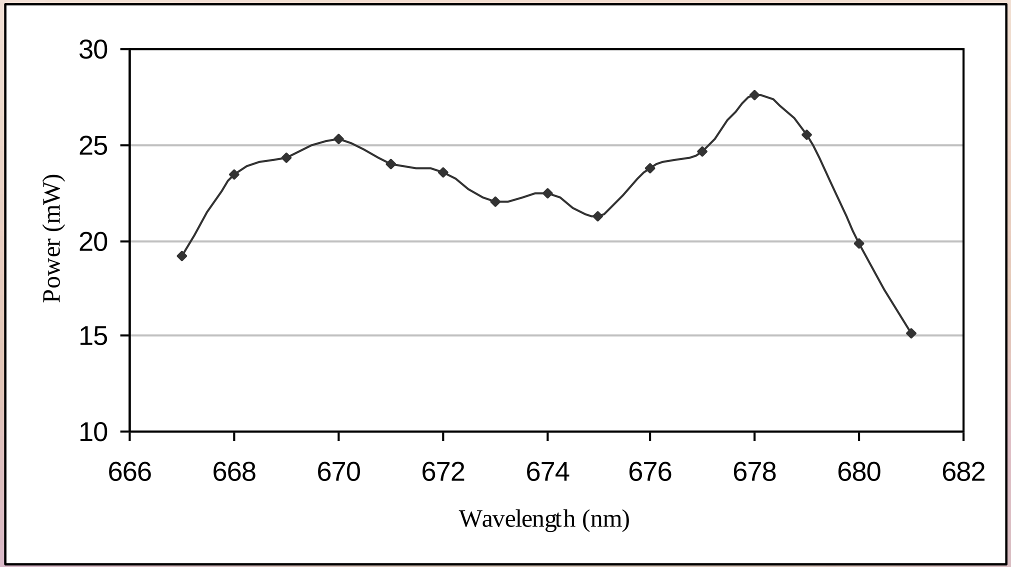
Laser Construction (Cont.)



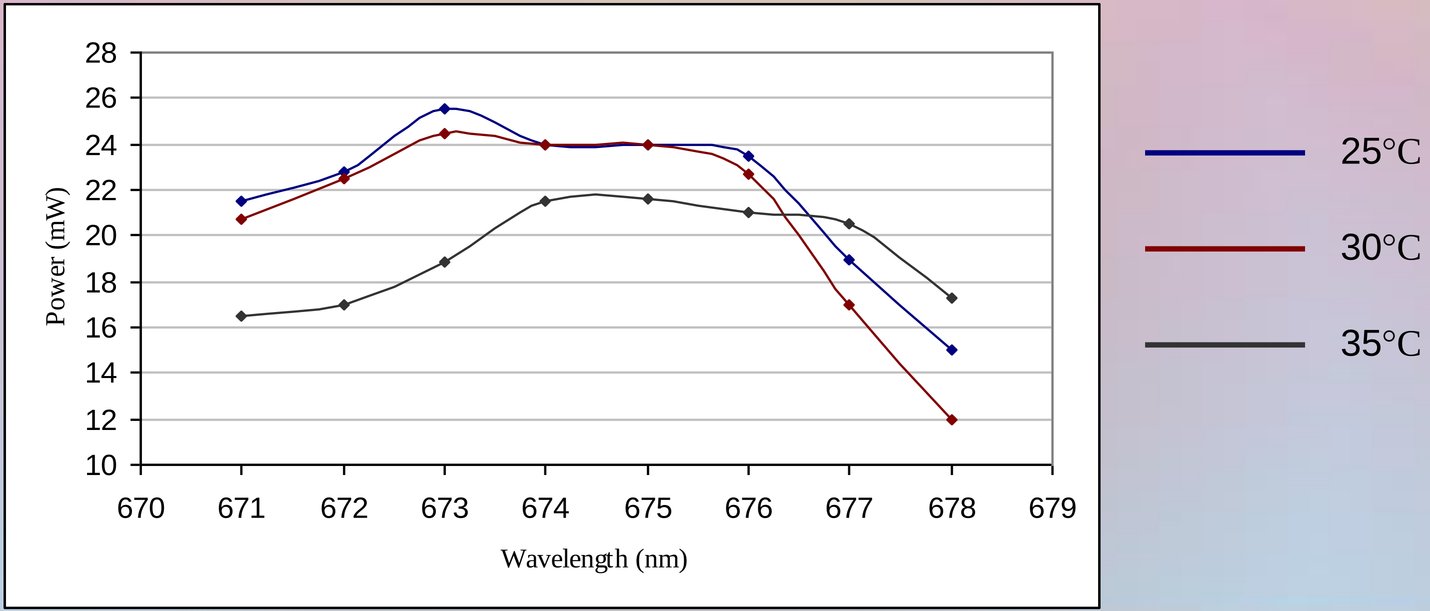
Initial Test Results



Test Results



Maximum Tunable Range at 25°C



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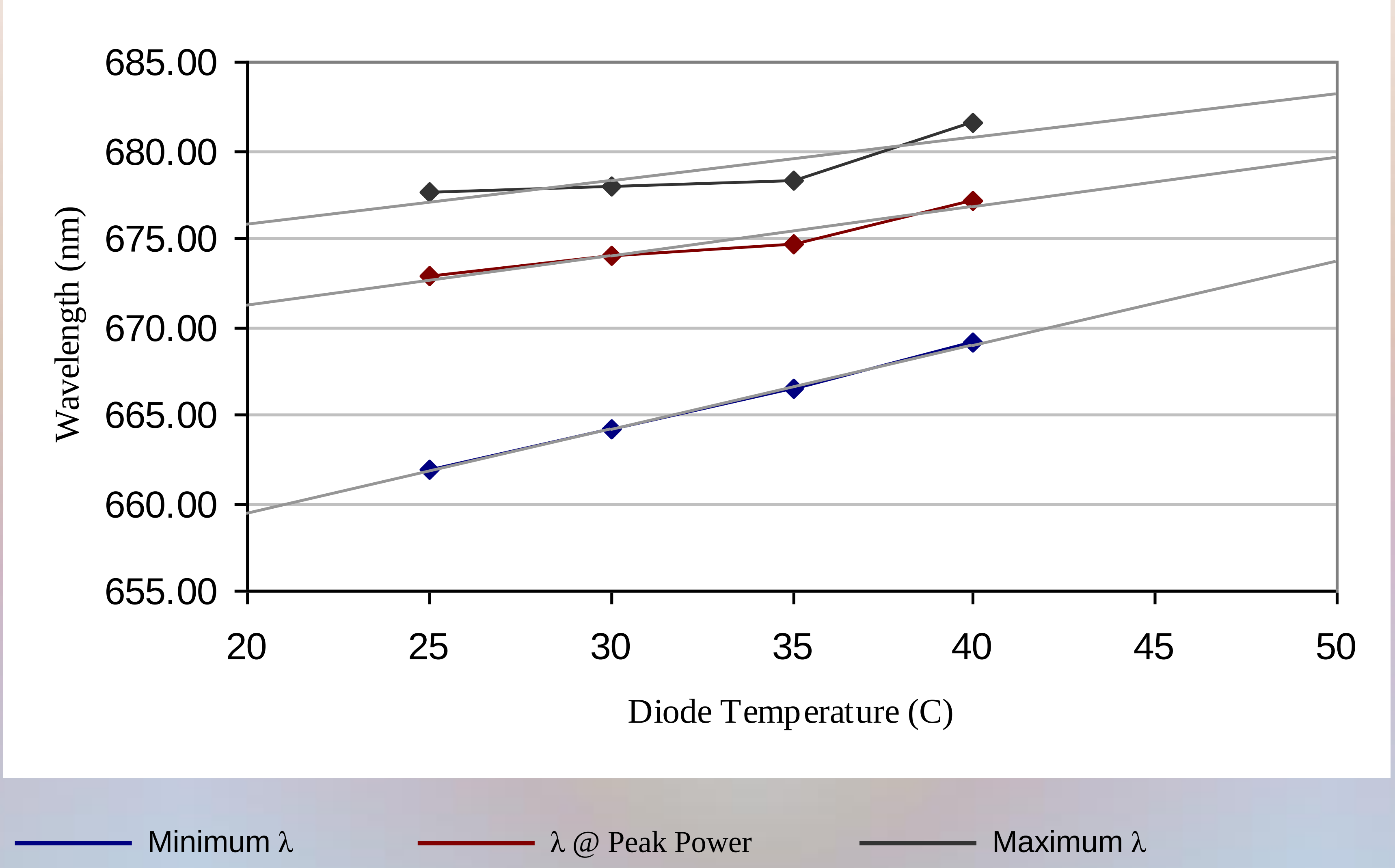

Results Summary

- PA laser performance exceeds expectation
  - Tunable range of ~20nm at room temperature
  - 30mW peak power at room temperature
  - Single-mode operation; sub-MHz linewidth

- *In the future…*
  - LiYb molecules!
  - Two-photon PA?

References

[1] http://www.nist.gov/public_affairs/images/06PHY006_YtterLaserCool_HR.jpg

[2] http://www.physics.ox.ac.uk/ultrafast/research/matter/overview.htm

[3] U. Schloder, C. Silber, C. Zimmermann: Appl. Phys. B **73**, 801 (2001)

[4] K. M. Jones, E. Tiesinga, P. D. Lett, P. S. Julienne: Rev. Modern Physics **78**, 483 (2006)

[5] C. J. Hawthorn, K. P. Weber, R. E. Scholten: Rev. Scientific Instruments **72**, 4477 (2001)