813nm Magic Wavelength Trapping for Strontium Atom

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Purpose

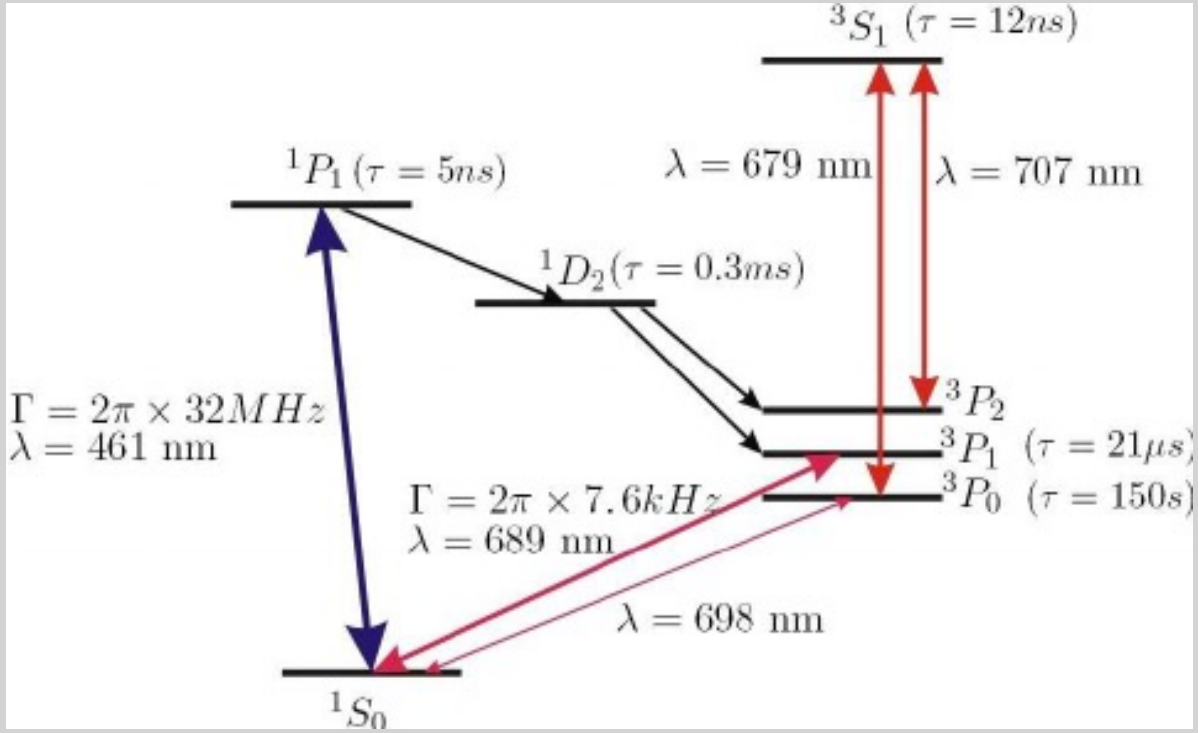
- Continuous Bose Einstein Condensation
- Observe wave nature of atoms by cooling down the atoms
- Continuous: atom laser
- Goal: cool down as many as atoms possible

Cooling on Sr Atoms

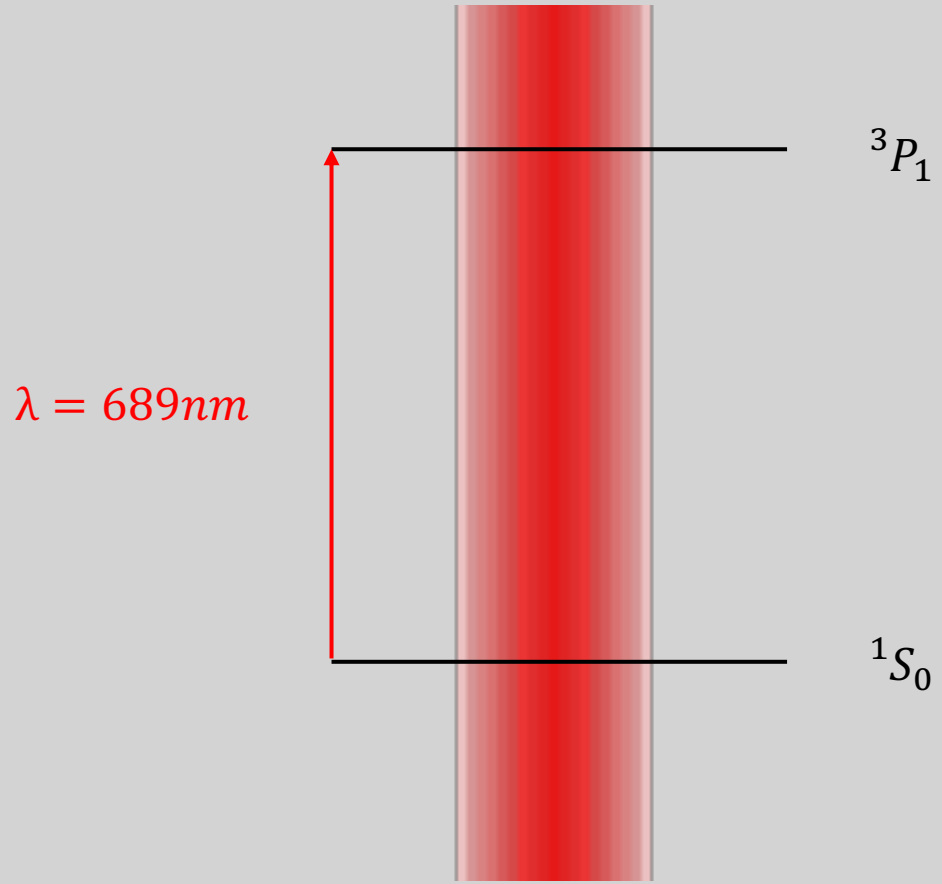
- Absorb photon to excite
- Atom slows down due to momentum change from photon

- Atom in excited state spontaneous decay
- Random direction
- Overall momentum change from scattering is balanced

- $^1S_0 - \ ^3P_1$ transition $(689nm)$

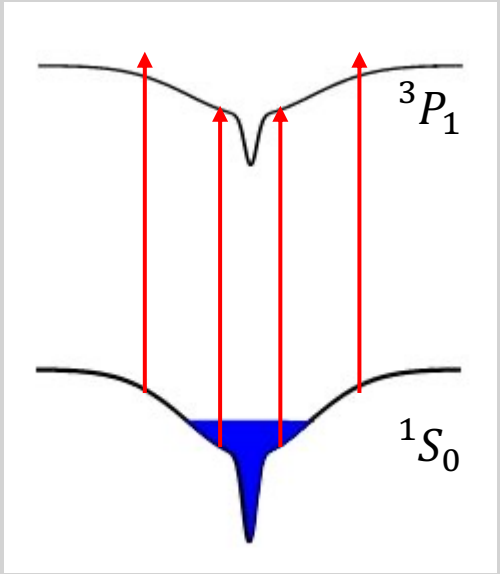


Precision Spectroscopy of Cold Strontium Atoms, Towards Optical Atomic Clock


$^3P_1$
$\lambda = 689nm$
$^1S_0$

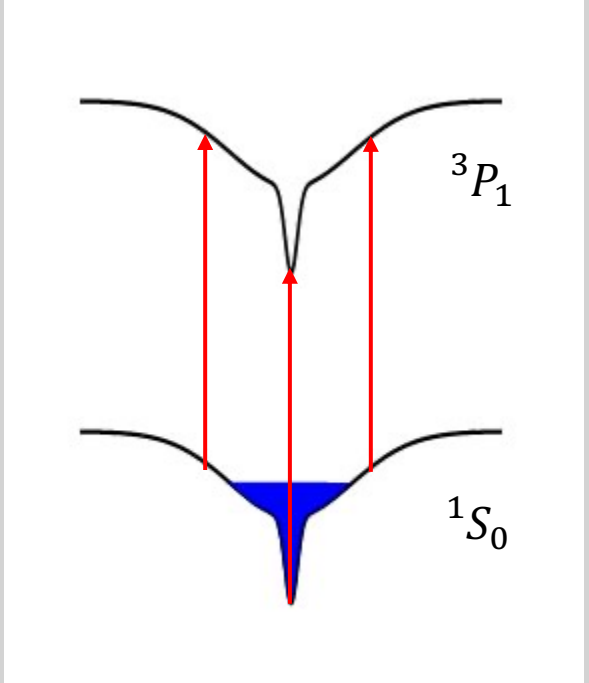
Light Shift on Two States

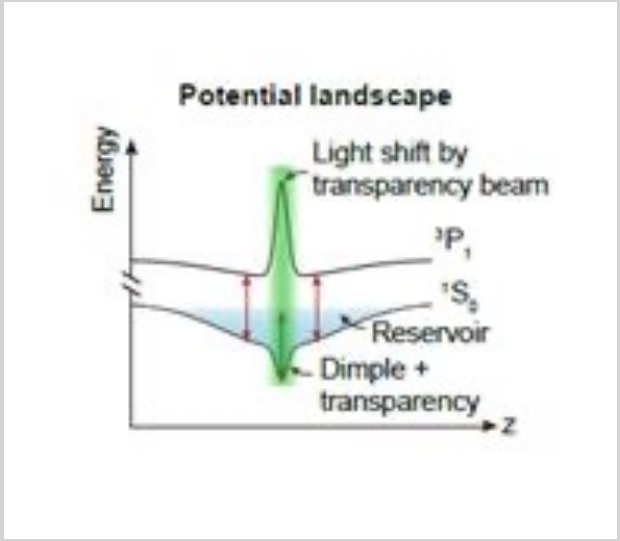
- Induce different trapping potential on the two cooling states
- Reduce cooling efficiency

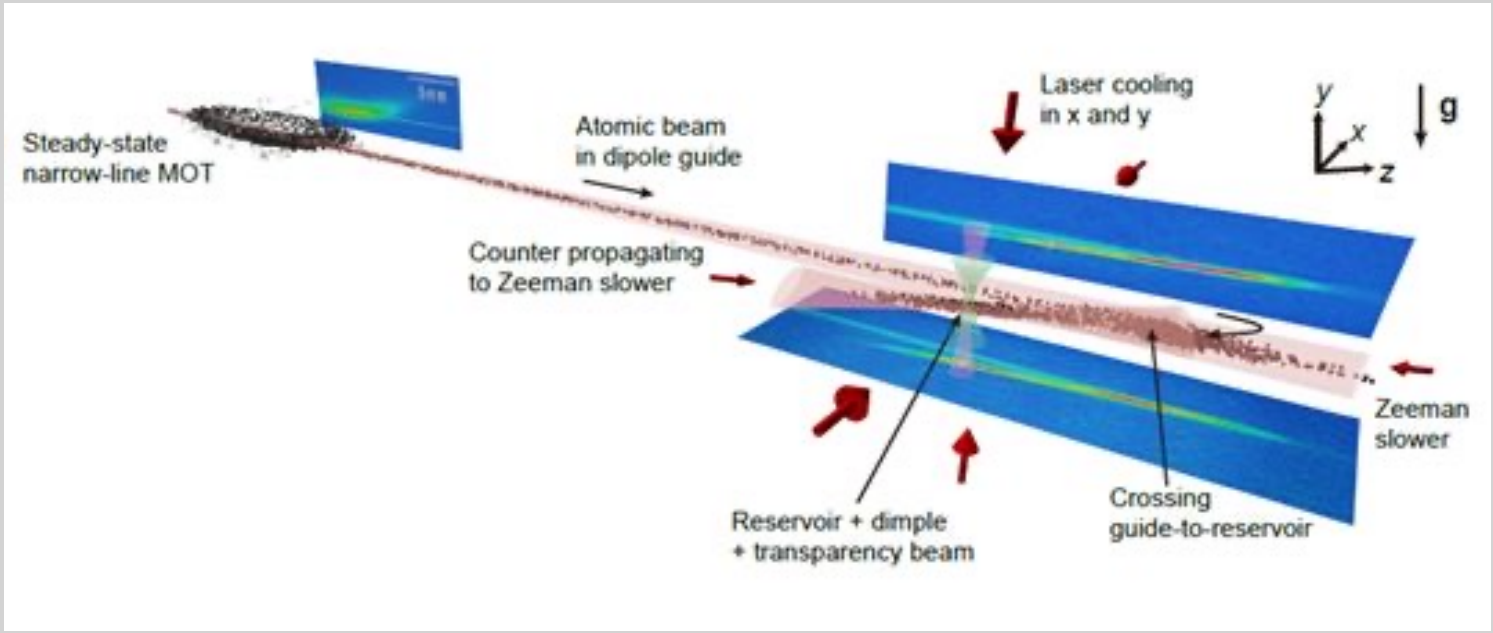


Solution for Different Potential

- Solution: make the potential the same
- Magic Wavelength: induce the same potential for two states
- 813nm (through calculation)




Potential landscape
Energy
Light shift by
transparency beam
$^3P_1$
$^1S_0$
Reservoir
Dimple +
transparency
z


Steady-state
narrow-line MOT
Atomic beam
in dipole guide
Laser cooling
in x and y
y
x
z
g
Counter propagating
to Zeeman slower
Zeeman
slower
Reservoir + dimple
+ transparency beam
Crossing
guide-to-reservoir

Requirement for Magic Wavelength Beam

- High power: $U \propto I$

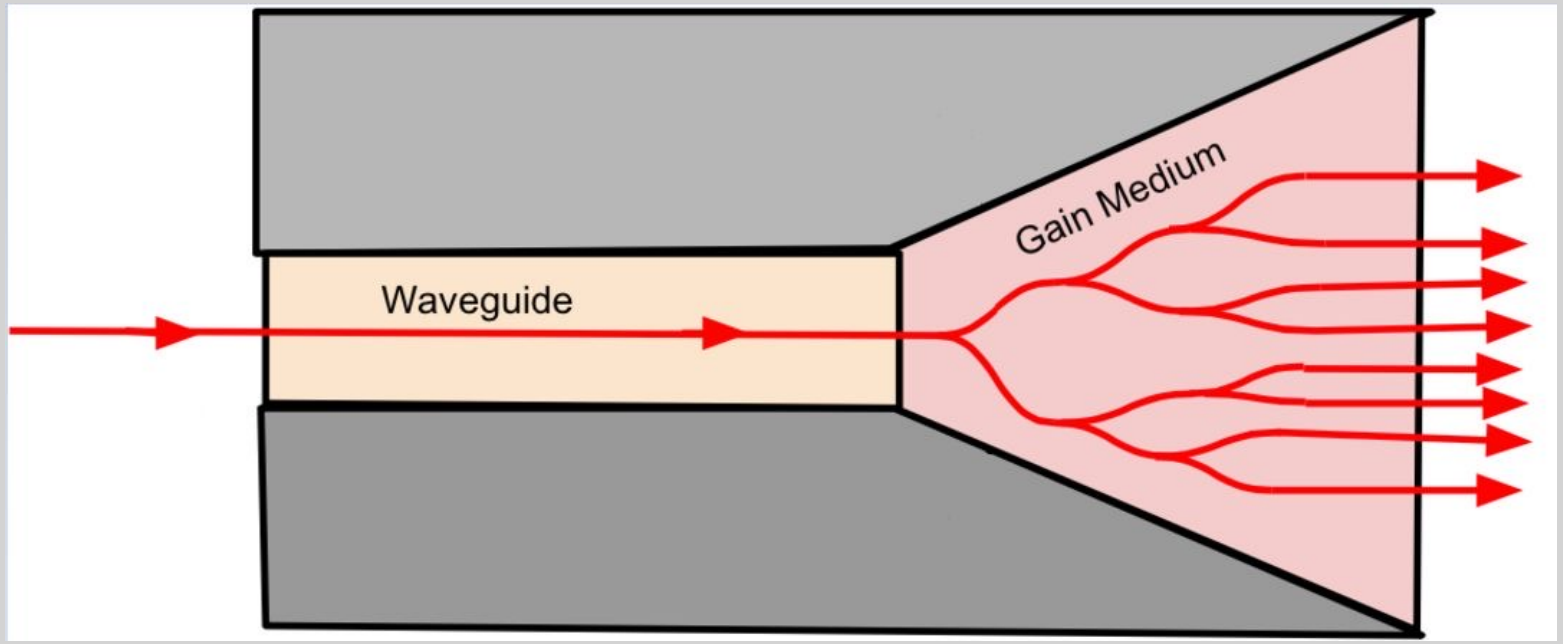
  Potential Intensity

- High power on normal laser: damage optical coating

Requirement for Magic Wavelength Beam

- Solution: Tapered Amplifier (TA)
- Larger cross section area → smaller intensity → protect optical coating

Small amount of 813nm laser light source



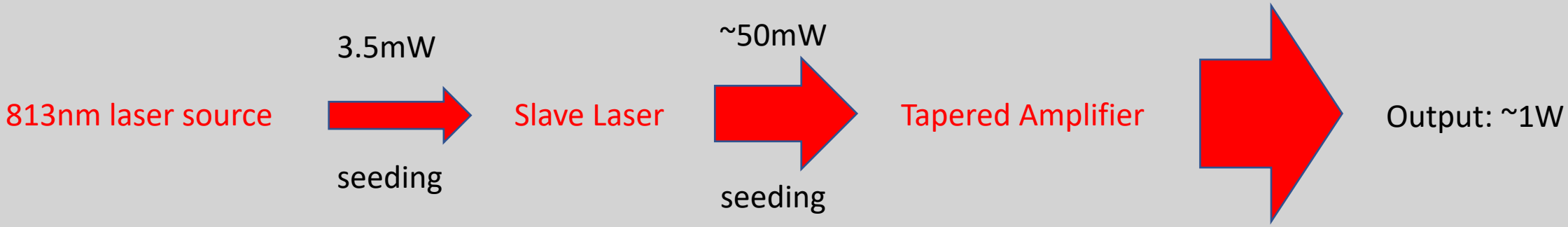
Huge amount of 813nm laser light source

Difficulty on Seeding Power?

- Available input power: ~3.5mW
- Solution: Slave laser Seeding a higher power laser diode with a source.

Recommended Operational Conditions

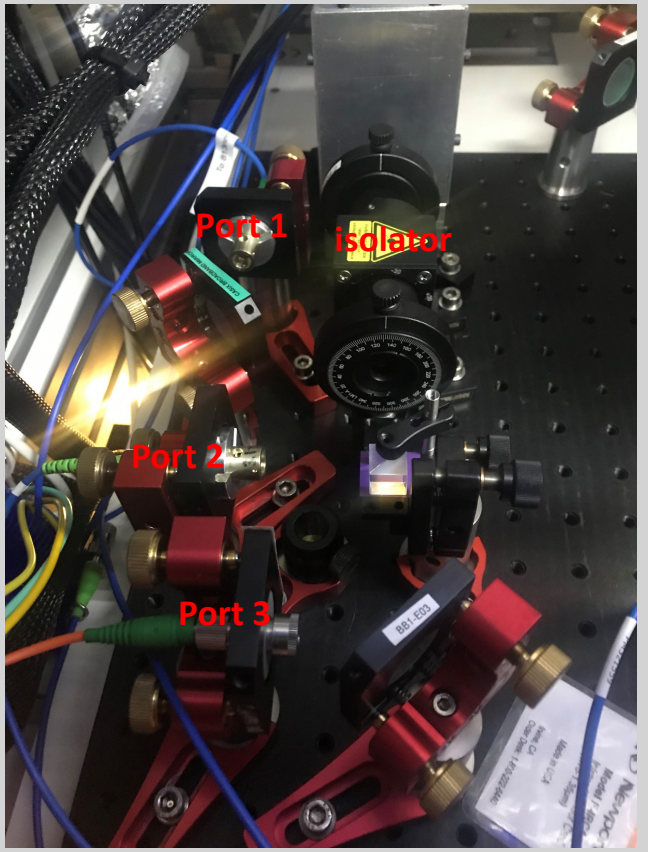
	Symbol	Unit	min	typ	max
Operational Temperature at Case	T_C	°C	5		40
Forward Current	I_F	A			4.0
Input Power	P_{input}	mW	10		50
Output Power	P_{opt}	W			2.0


813nm laser source
3.5mW
seeding
Slave Laser
~50mW
seeding
Tapered Amplifier
Output: ~1W

Slave Laser – Injection Lock

- Isolator
  - light cannot pass back from transmitted path
  - ensure same polarization for seeding
- Temperature: 23°C
  - Lower temperature, closer to 813nm
  - Further low temperature may cause dews
- Port 1: seeding port (~3.5mW)
- Port 2: Output for TA Seeding
- Port 3: fabry-perot cavity (check injection lock)

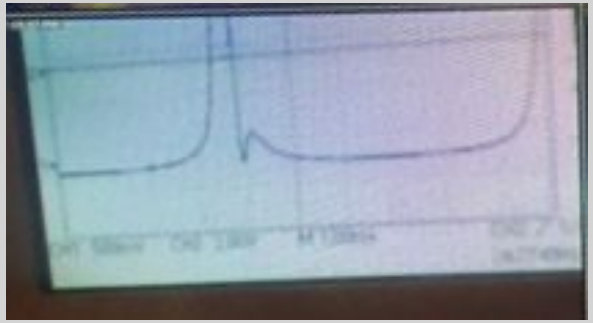
L820P100 Specifications				
	Symbol	Min	Typical	Max
Center Wavelength @ P_{op}	λ_o	808 nm	820 nm	828 nm
Output Power, CW	P_{op}	-	100 mW	-
Threshold Current	I_{TH}	-	40 mA	70 mA
Operating Current CW @ P_{op}	I_{op}	-	145 mA	210 mA

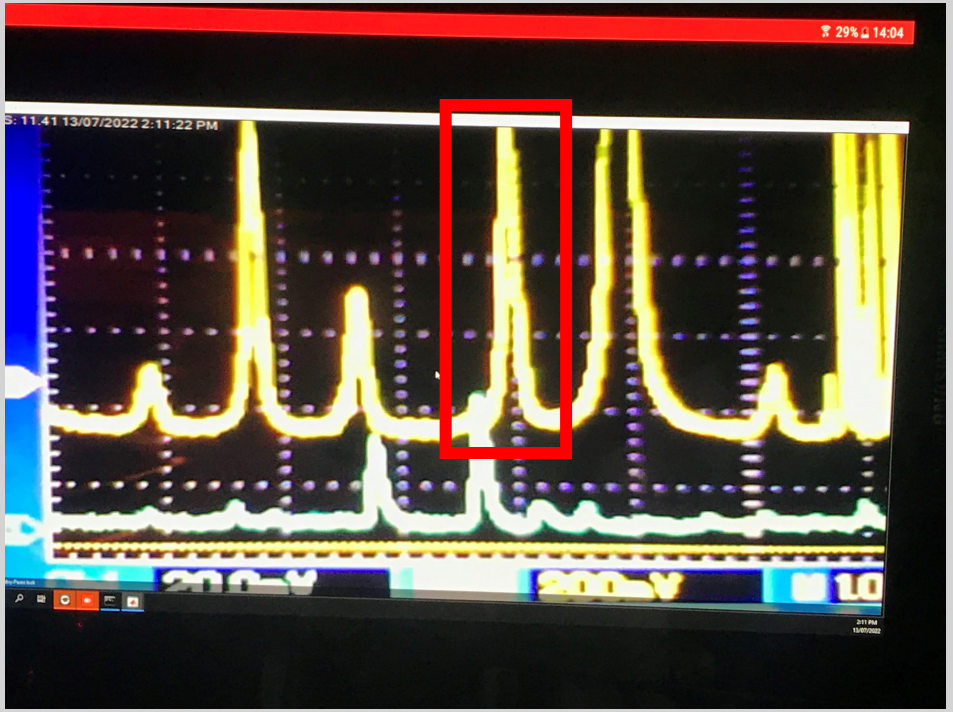


Slave Laser – Injection Lock

Seeding Power: 2.35mW
Single mode current range (mA)
45(threshold) - 100
114 - 121.5

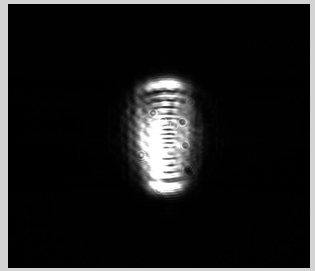
Seeding Power (mW)	Single Mode Current Range (mA)	Power after Isolator(mW)
2.87	114 - 121.5	56
2.03	114.5 - 121	56
1.03	114.5 - 121	55.8
0.75	116.5 - 121	56
0.525	118 - 121.3	55.6
0.255	118.5 - 121.9	55.4
0.106	118.5 - 121.5	55.4
Lowest possible seeding power = 0.1mW		





Efficiency for the Output to TA Seeding

- Fibre coupling efficiency for TA seeding
  = 31.33/55
  = 56.96%

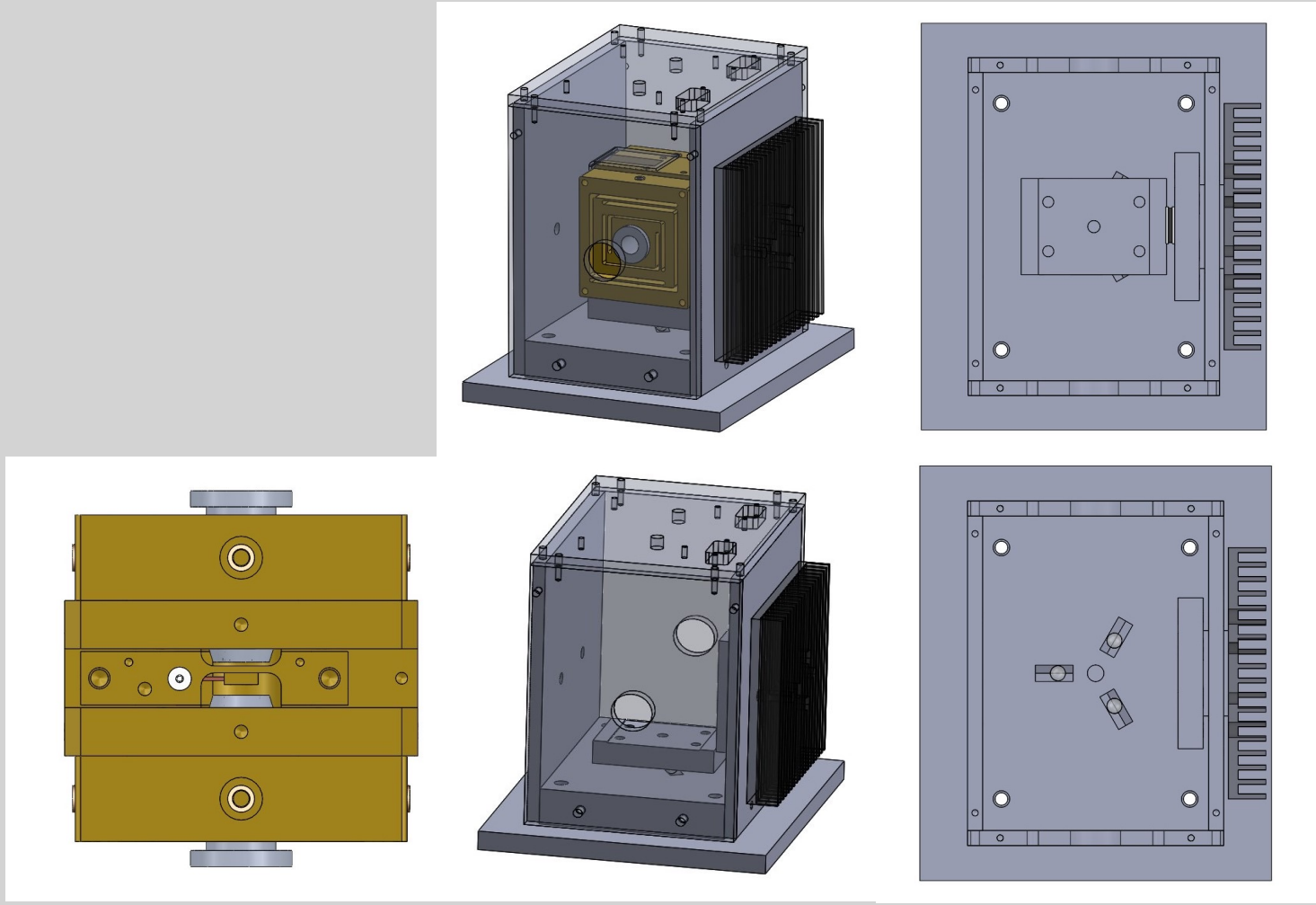


- Low fibre coupling efficiency mainly due to bad beam shape

- TA seeding power: 31.33mW

TA Box Design

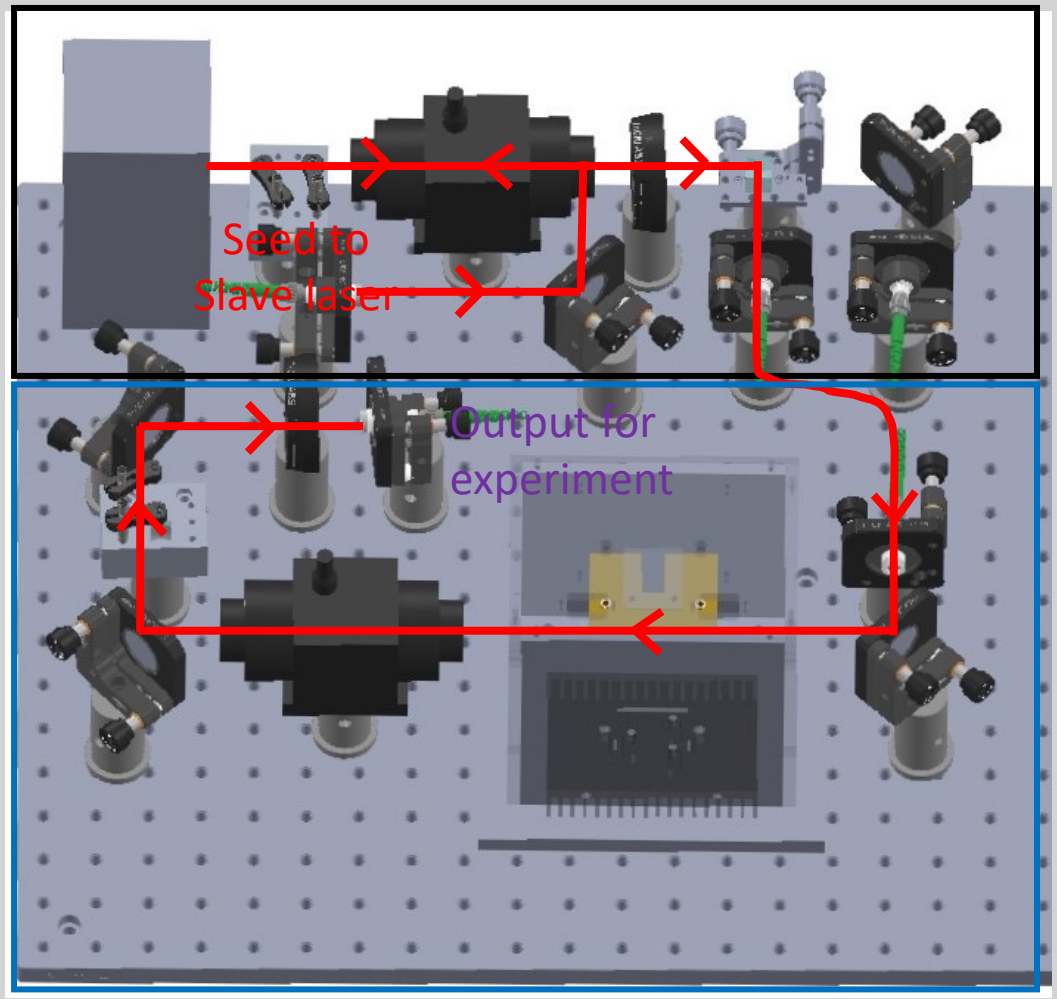
- Heat sink on the wall
  - reduce direct heat to the table
- Three ball holder design
  - Thermal insulation
- Open holes on the sides of the box
  - Tunable alignment
- Common ground for the whole holder
  - avoid shorting when putting screw driver for adjustment

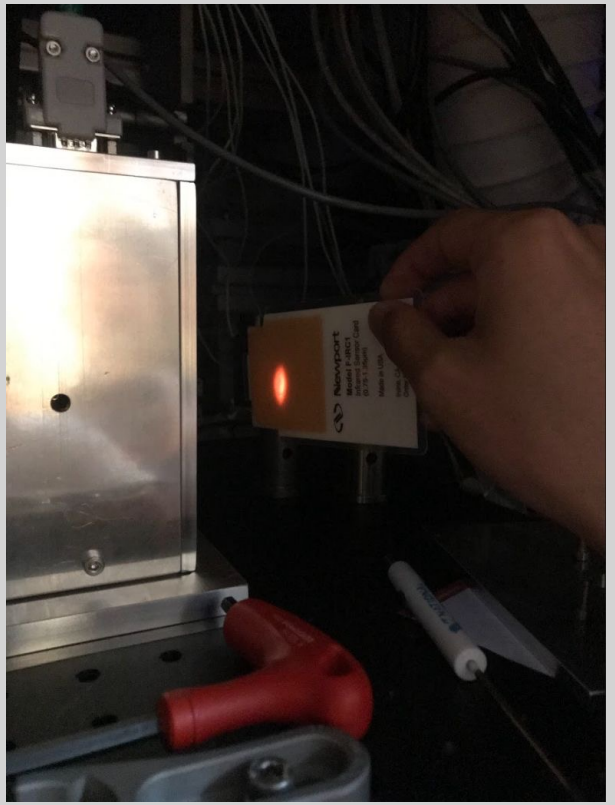


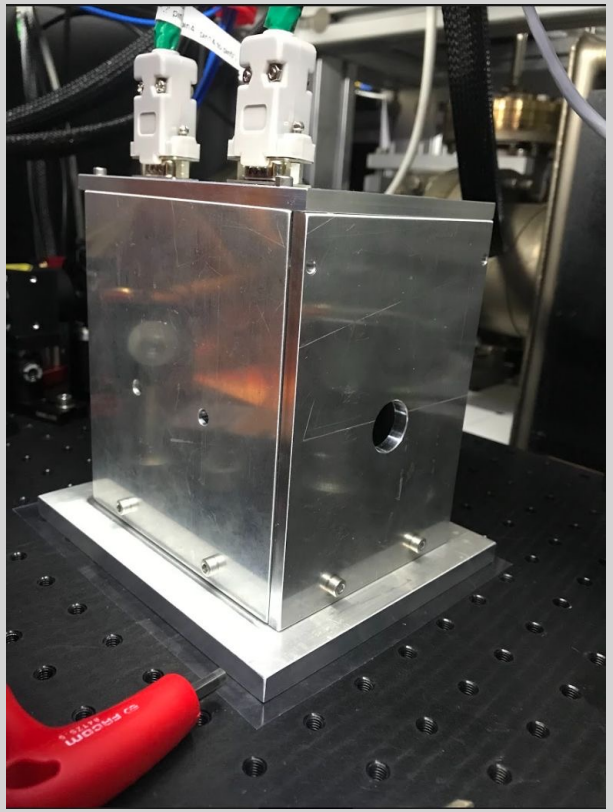
Optical Setup & TA Assemble

Setup of slave laser

Setup of TA

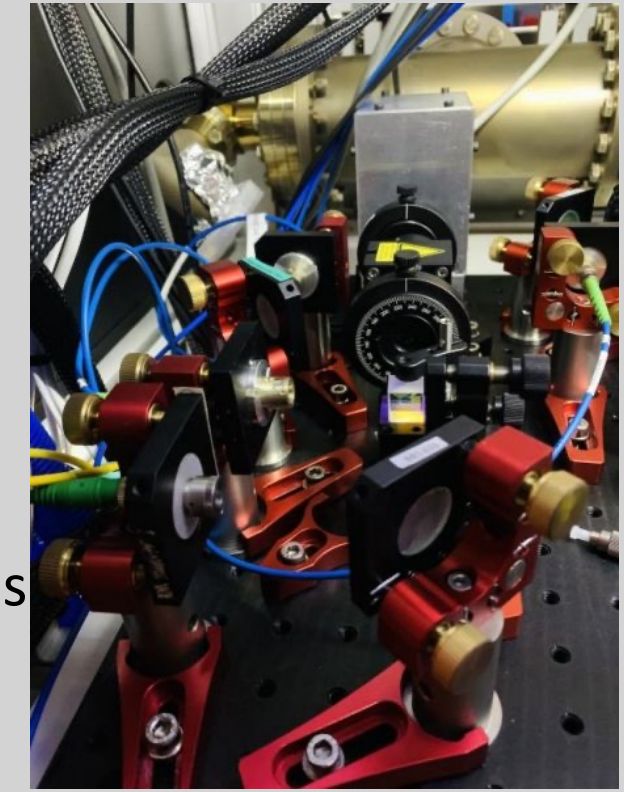


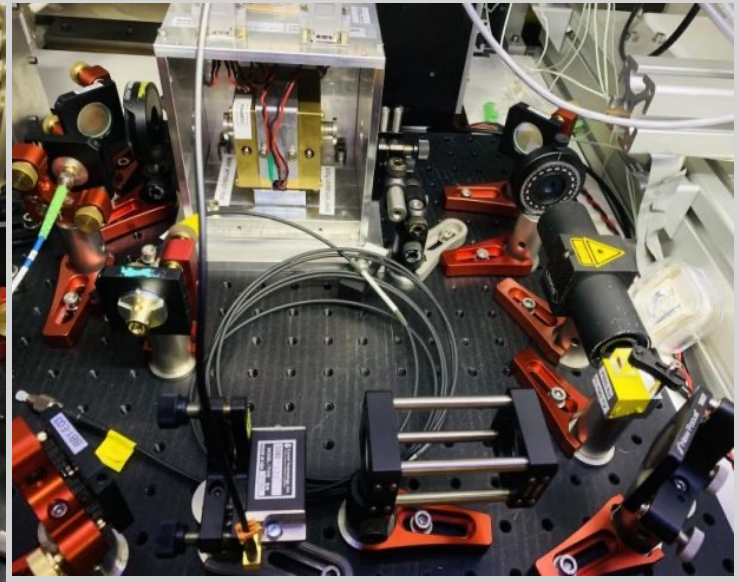




Follow Up & Bugs

- Temperature not stable
  - Large box
  - Thermistor and TEC are far away
  - time difference in sensing the heat and responding the heat
  - Solution:
    put thermistor closer to TEC





- Different beam focus for different axis
  - Astigmatism
  - One of the beam axis expand too fast
  - Lens cannot cover the whole beam
  - Solution:
    put a post to hold the lens with smaller focus length inside the box

Acknowledgement

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Thank You