Injection locking of a high power ultraviolet laser diode for laser cooling of ytterbium atoms

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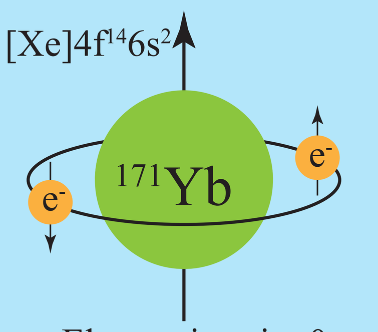
INTRODUCTION

Ytterbium (Yb)

Electron configuration

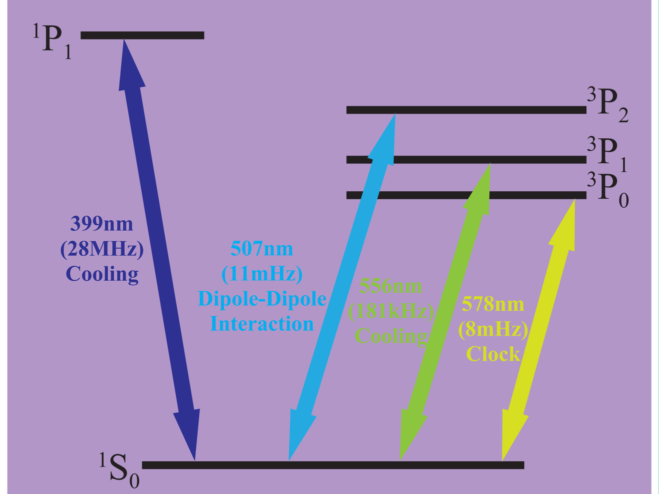
[Xe]$4f^{14}6s^2$



Electronic spin: 0
Nuclear spin: 1/2

Small magnetic moment
→ Long coherence

Optical Transitions



Several optical transitions

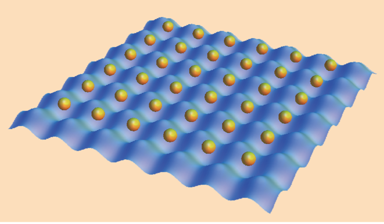
Isotopes

Isotope	Abundance	Type	Spin
168	0.13%	Boson	0
170	3.05%	Boson	0
171	14.3%	Fermion	1/2
172	21.9%	Boson	0
173	16.12%	Fermion	5/2
174	31.8%	Boson	0
176	12.7%	Boson	0

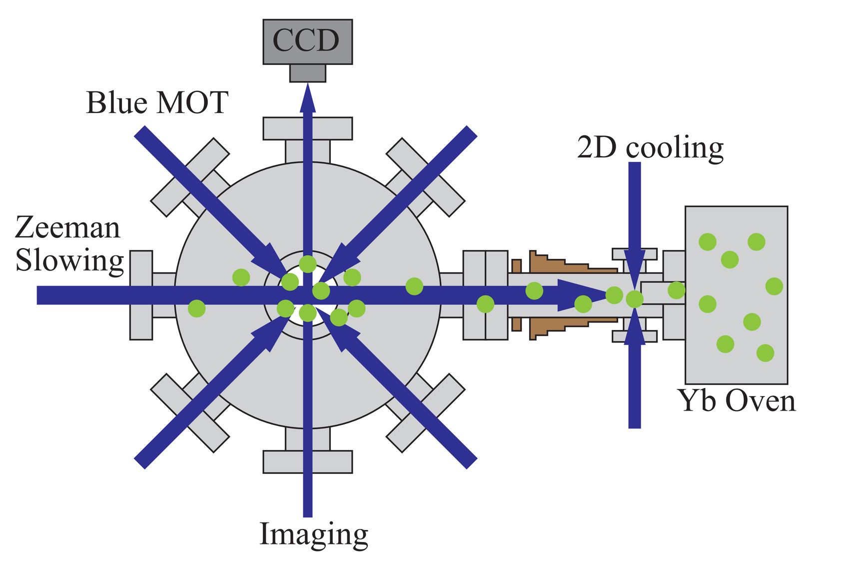
Seven isotopes including fermions and bosons

Applications

- Quantum computers
- Quantum simulator
- Optical lattice clocks
- etc



The dipole-allowed $^1S_0$-$^1P_1$ transition (399nm-28MHz)

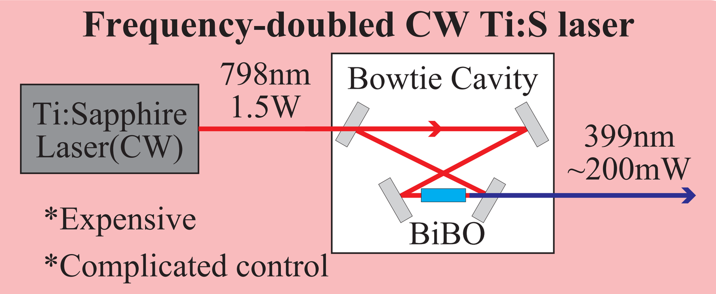


Applications of 399nm laser

- Zeeman Slowing
- Blue MOT
- 2D Cooling
- Imaging
- etc

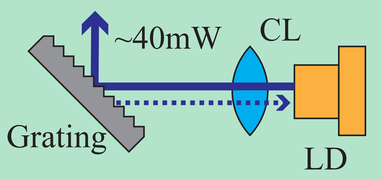
Light sources at 399nm

Frequency-doubled CW Ti:S laser



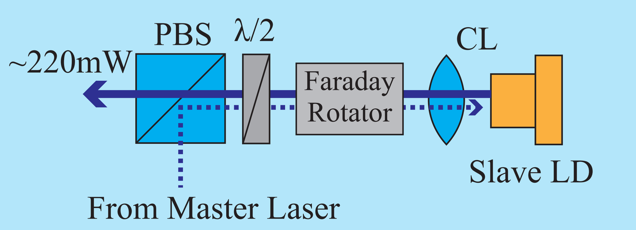
*Expensive
*Complicated control

External Cavity Laser Diode (ECLD)



*It is difficult to operate stably at a high power

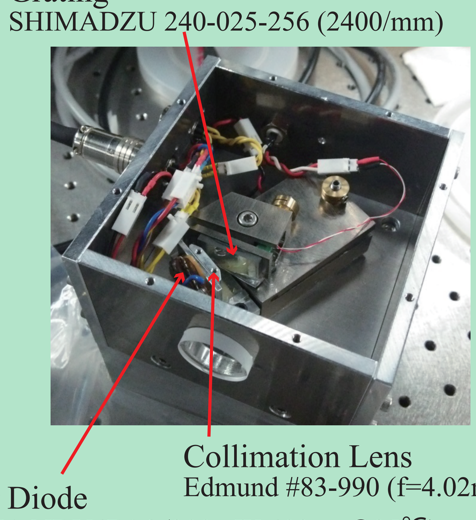
Injection Locking



SETUP

Master Laser (ECLD)

Grating
SHIMADZU 240-025-256 (2400/mm)

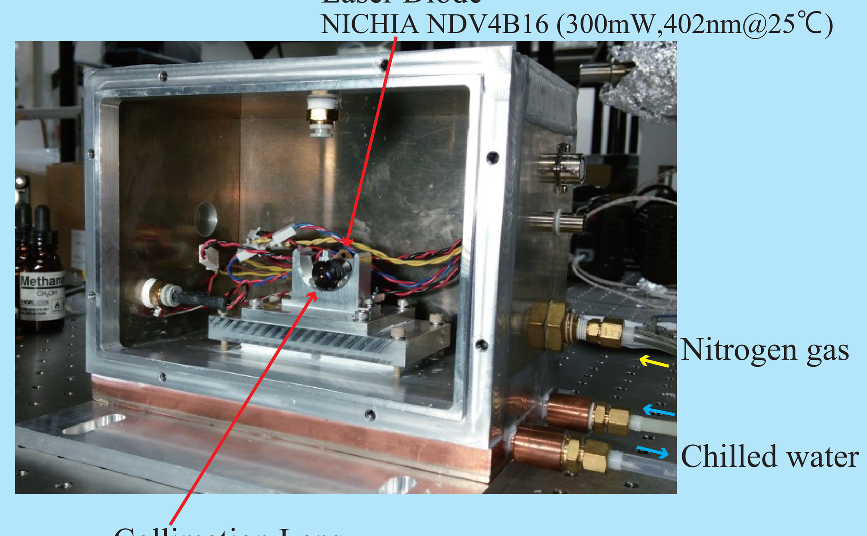


Collimation Lens
Edmund #83-990 (f=4.02mm, 0.60NA)
Laser Diode
NICHIA NDV4B16 (300mW,402nm@25℃)

*Output Power: 40mW
*Operating Temperature: 18 ℃
*Wavelength: 399nm
-The wavelength was locked using the saturated absorption signal of the $^1S_0$-$^1P_1$ transition in ^{174}Yb atoms obtained with an Yb Hollow-cathode lamp(HCL).

Slave LD

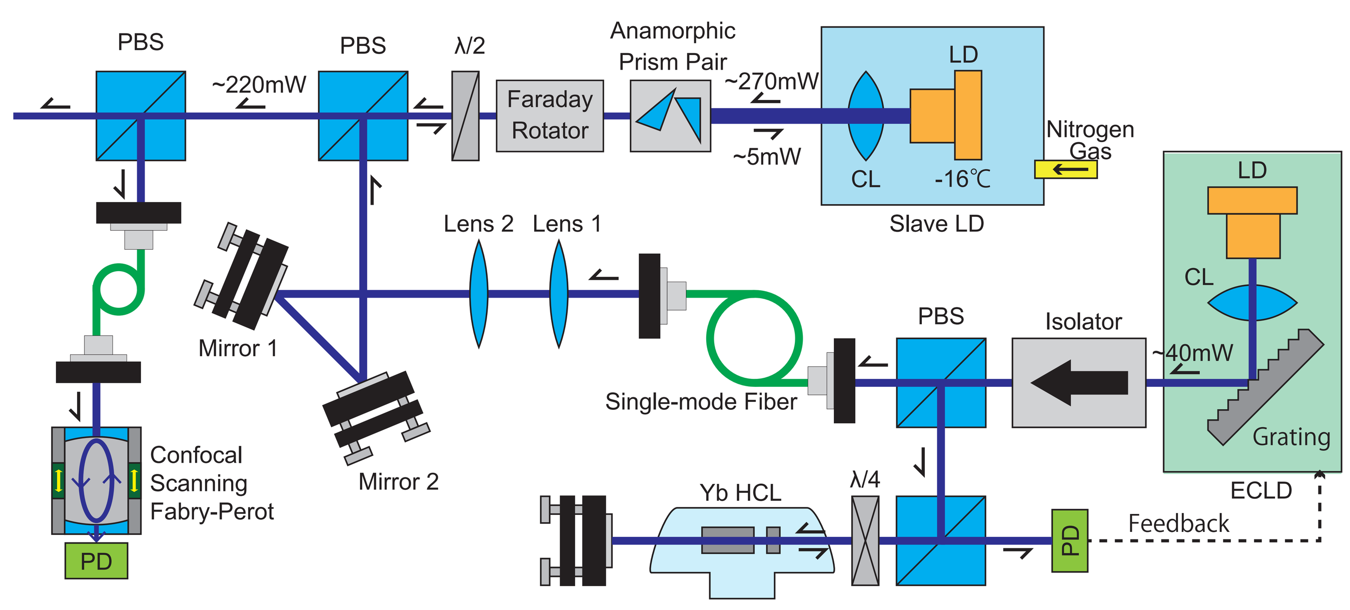
Laser Diode
NICHIA NDV4B16 (300mW,402nm@25℃)



Collimation Lens
Melles Griot 06GLC201 (f=6.5mm, 0.615NA)

*Output Power: 220mW
*Injection Power: 5mW (from ECLD)
*Operating Temperature: -16 ℃
-In order to avoid condensation, we created a box with air-tight seal and purged the box with nitrogen gas.

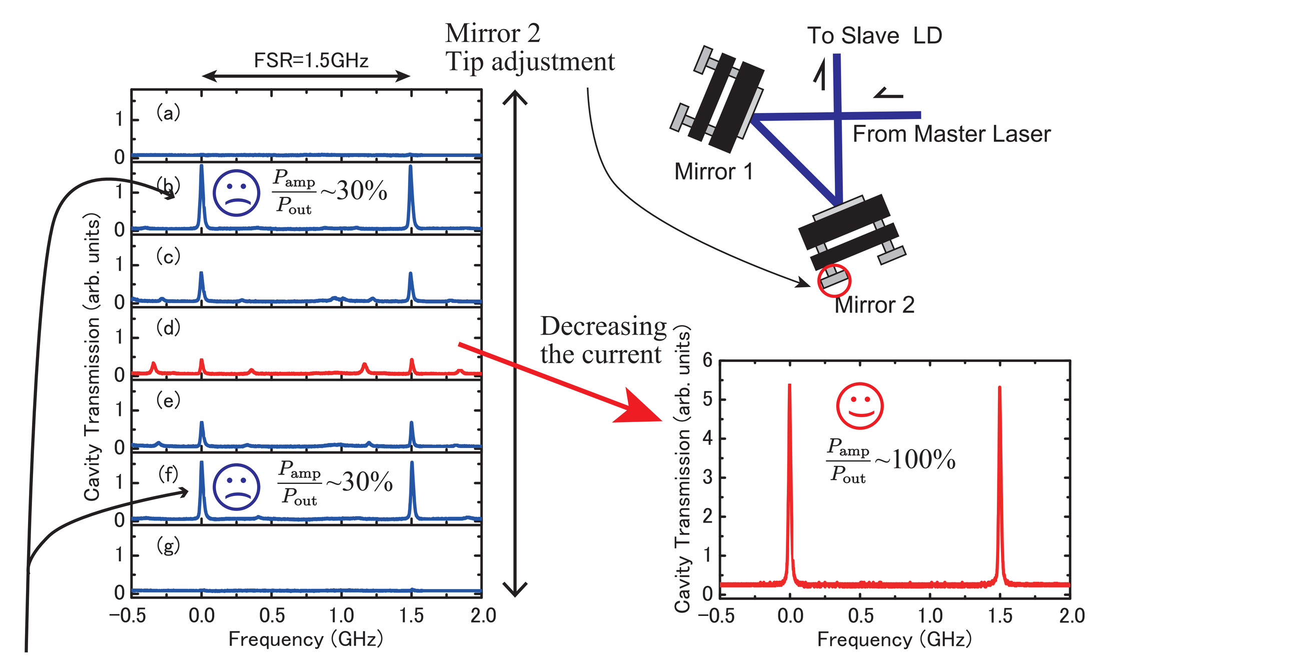
Experimental Setup



The lenses 1 and 2, mirrors 1 and 2, and anamorphic prism pair were placed for mode matching.

RESULTS

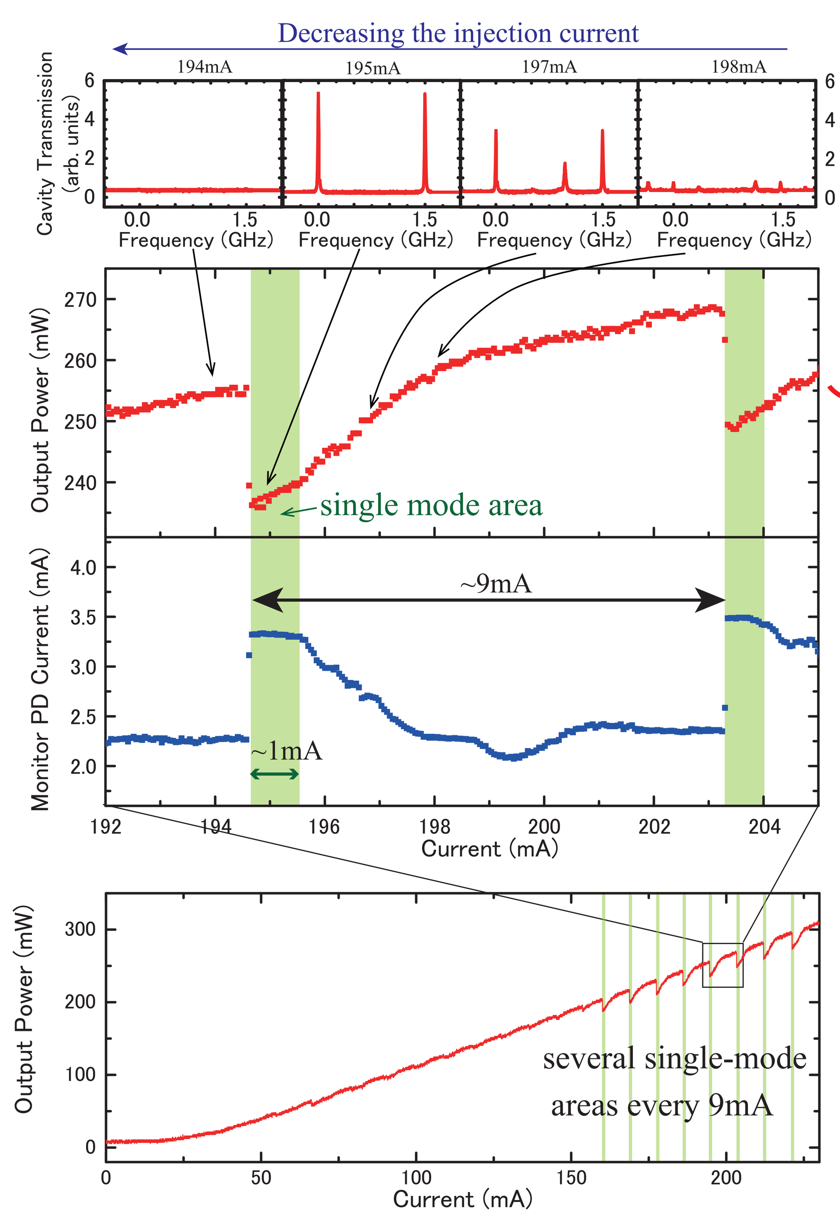
The adjustment techniques by using Fabry-Perot signals



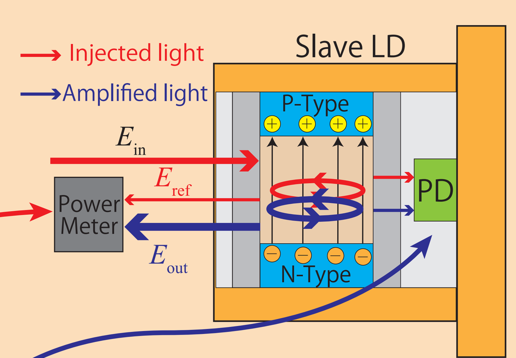
These signals look like single frequency mode. However, only 30% of output power was single mode.

When the injection current was decreased, 100% of the laser oscillation became single frequency mode.

Injection-current dependence.



What happened?

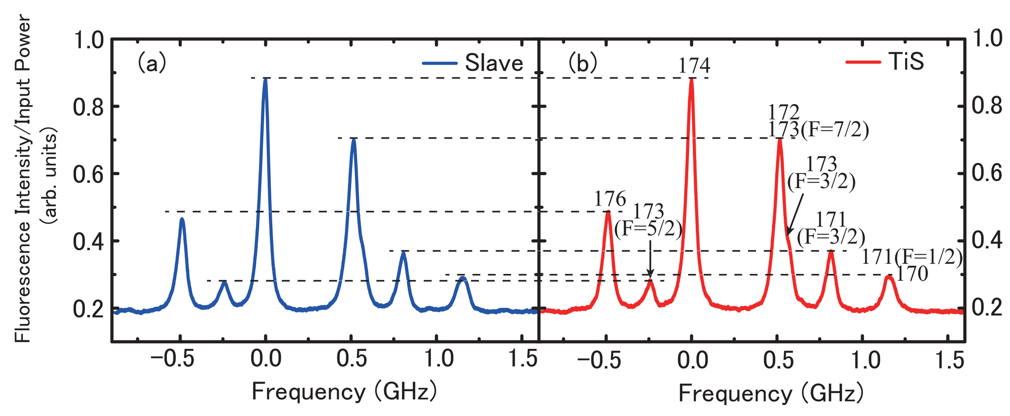


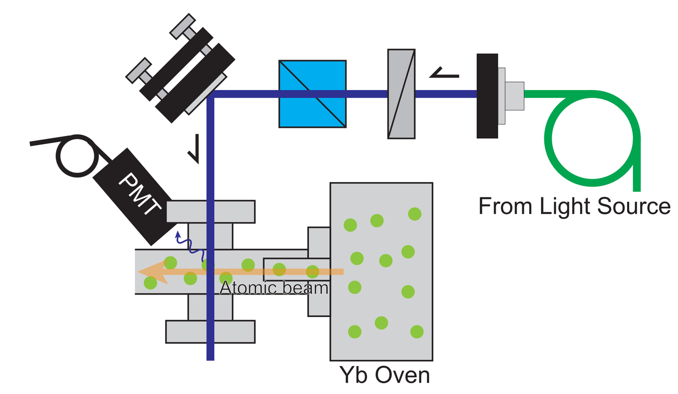
$E_{in} = |E_{in}| \exp[\, i\,(kx - \omega t)\,]$
$E_{ref} = |E_{ref}| \exp[\, i\,(-kx - \omega t + \pi)\,]$
$E_{out} = |E_{out}| \exp[\, i\,(-kx - \omega t + 2\pi n)\,]$
$E_{PM} = (\,|E_{out}| - |E_{ref}|\,) \exp[\, i\,(-kx - \omega t)\,]$

The output power decreased because the reflected light from the LD face negatively interfered with the amplified light.

On the other hand, the monitor PD current increases when the injected light couples with the cavity.

Spectroscopy of the $^1S_0$-$^1P_1$ transition





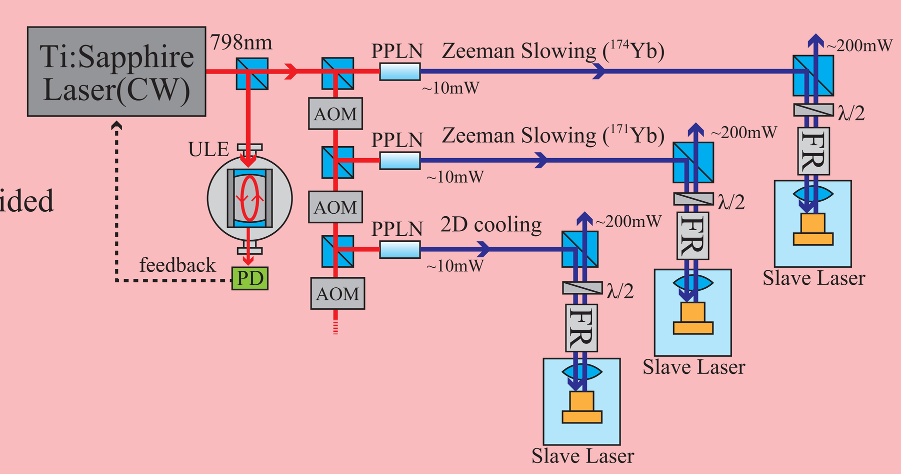
We checked the ratio of amplified frequency power in the output power using the Yb spectrum obtained from the atomic beam fluorescence (saturation parameter = 0.004). We compared the atomic beam fluorescence of the slave LD and the frequency-doubled CW Ti:S laser. The master laser source was prepared by using the frequency-doubled CW Ti:S laser.

CONCLUSIONS

We implemented a systematic method for adjusting the injection locking using a Fabry-Perot signal.
There were several injected current areas in which the slave LD output became single frequency mode .
We developed 220mW light source at 399nm for laser cooling of ytterbium atoms with an ultraviolet laser diode by using injection locking.

APPLICATION

Multiple laser sources can be easily provided by using our method.



OUR GROUP

(Thu-102)
We have succeeded in implementing a quantum gas microscope of ytterbium atoms !

Professor	Mikio Kozuma
Assistant Professor	Ryotaro Inoue
Students	Martin Miranda Toshiyuki Hosoya Izumi Shomura Keiji Nishida Naoki Tambo Yuki Miyazawa