Repumping laser for laser cooling of caesium

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Laser cooling of caesium

- I have commercially available laser with well defined frequency (cooling beam, master)
- I need to build a semiconductor laser (repumping beam, slave)
- $\omega_{\text{repumping}} - \omega_{\text{cooling}} \approx 9.2\,\text{GHz}$
Constructed semiconductor laser

Semiconductor laser elements: 1) optical isolator, 2) collimation tube, 3) laser diode, 4) electronic temperature sensor, 5) collimator holder, 6) cooling element (Peltier module), 7) base, 8) cover.

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Current and temperature control

- **stability** – minimized changes in spectrum and energy gap of active medium
- **repeatability** of work conditions
Semiconductor laser diode

- Parameters: 852 nm, 100 mW
- Active medium: p-n junction

Sample L852P100 L-I-V Characteristics

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Laser action

\[ I_{th} = 23.0 \, mA \]

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Optical injection locking

Why injection locking?

- relatively easy way for tuning
- well defined frequency (exactly the same as the master’s)
Threshold current change

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Fabry-Perot cavity measurements: injection window

Seeding windows for different powers of injected light and light spectra observed in Fabry-Perot cavity. Blue dots correspond to parameters for which the spectra b)-e) were measured. There was no injection seeding for point b).
Saturated absorption spectroscopy

The saturated absorption spectrum of D1 line transitions of caesium from $F = 3$ ground energy level for i) ECDL laser, ii) slave laser.

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SAS injection window and window widths comparison

a) Injection locking window for scanned master frequency, b) comparison of injection window width for master frequency locked to atomic transition (blue squares) and scanned (red circles)
Laser diode current modulation

DC – direct current
RF – alternating current with $\omega_0$ frequency

Bias tee

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Creation of sidebands in the spectrum

(a) no modulation
(b) modulation with RF current $\omega_0 \approx 3\,GHz$

Sidebands appear for frequencies equal to $\omega_0 \pm n\omega_m$, $n = \pm 1, 2, 3, ...$

$\omega_0$ - frequency of the laser
$\omega_m$ - RF current frequency

P. N. Melentiev, M. V. Subbotin, and V. I. Balykin, *Simple and Effective Modulation of Diode Lasers*
Current modulation in laser diode

\[ E = E_0 \exp[i(\omega_0 t + \beta \sin(\omega_m t))] \]
\[ \beta = 2\pi \Delta F / \omega_m \]

\( \Delta F \) - maximum frequency deviation

\( \beta \) – modulation index

\( \omega_0 \) - laser radiation frequency

\( \omega_m \) – frequency of the modulation current
Final setup

FR signal generator $\approx 9\,GHz$

current controller

slave

optical isolator

$\lambda/2$

PBS

repumping beam

master

optical isolator

cooling beam

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Advantages of my setup

• about ten times cheaper than a commercial laser

• no need for expensive elements to obtain desired frequency

• master and slave are phase coherent

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