Analysis and Generation of Frequency Sidebands in a Lithium Niobate Phase Modular

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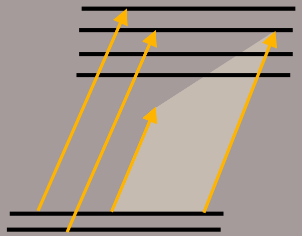
What's the Big Idea?

Single laser generation of frequencies for simultaneous generation of:

- Magneto-Optical Trap Cycling Transition
- Magneto-Optical Trap Repump Transition
- Frequency-Modulated Light for Ultracold Collision Experiments
- Frequency-Modulated Light for Controlling Atomic Excitation*

*See Other team's poster



Requirements!

- Frequency-referenced to Rb MOT cycling transition
- Generate Chirp rates > 1 GHz in 10 ns for 10 ns pulses
- Generate a controllable sideband at 2.9 GHz for repump
- Be able to tune the center frequency of frequency chirp.

$$\cos(2\pi f_c t + \beta \sin(2\pi f_m t)) = \sum_{k=-\infty}^{\infty} J_k(\beta)\cos(2\pi(f_c + k f_m)t)$$

$$\begin{aligned}\cos(A+B) &= \cos A\cos B - \sin A \sin B\\ 2\cos A\cos B &= \cos(A-B) + \cos(A+B)\\ 2\sin A \sin B &= \cos(A-B) - \cos(A+B)\end{aligned}$$

$$\cos(z\sin\theta) = J_0(z) + 2\sum_{k=1}^{\infty} J_{2k}(z)\cos(2k\theta)$$

$$\sin(z\sin\theta) = 2\sum_{k=0}^{\infty} J_{2k+1}(z)\sin((2k+1)\theta)$$

$$J_{-n}(z) = (-1)^n J_n(z)$$

$$\cos(2\pi f_c t + \beta\sin(2\pi f_m t))$$

$$\cos(2\pi f_c t)\cos(\beta\sin(2\pi f_m t)) - \sin(2\pi f_c t)\sin(\beta\sin(2\pi f_m t))$$

$$\cos(2\pi f_c t)\cos(\beta\sin(2\pi f_m t))$$

$$J_0(\beta)\cos(2\pi f_c t) + \sum_{k=} J_{2k}(\beta)\{\cos(2\pi(f_c - 2k f_m)t) + \cos(2\pi(f_c + 2k f_m)t)\}$$

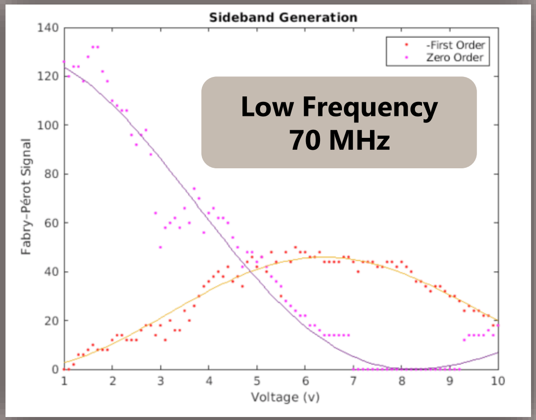
$$\sum_{n\ \text{even}} J_n(\beta)\cos(2\pi(f_c + n f_m)t)$$

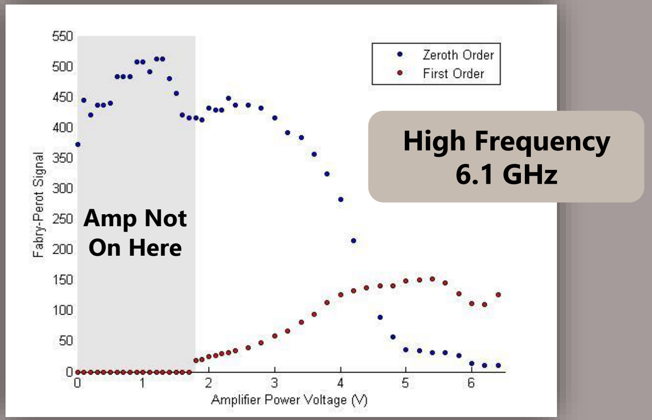
$$\sin(2\pi f_c t)\sin(\beta\sin(2\pi f_m t))$$

$$\sum_{k=1}^{\infty} J_{2k+1}(\beta)\{\cos(2\pi(f_c - (2k+1)f_m)t) - \cos(2\pi(f_c + (2k+1)f_m)t)\}$$

$$-\sum_{n\ \text{odd}} J_n(\beta)\cos(2\pi(f_c + n f_m)t)$$

$$\cos(2\pi f_c t + \beta\sin(2\pi f_m t)) = \sum_{k=-\infty}^{\infty} J_k(\beta)\cos(2\pi(f_c + k f_m)t)$$



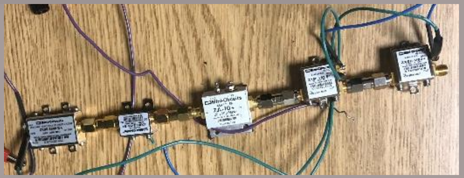


Solution

- Mod. range dependent on mod. Freq.
- Solution:
  - Frequency-referenced to Rb Repump transition
  - Generate Chirp rates in sidebands > 1 GHz in 10 ns for 10 ns pulses
  - Generate a controllable sideband at 6.8 GHz for cycling transition
  - Be able to tune the center frequency of frequency chirp

Frequency modulation combines a signal with a carrier wave by modulating the carrier wave's frequency. In order to understand this signal in terms of cosines without any frequency modulation, the derivation above shows the result is a set of cosines weighted by Bessel functions of β

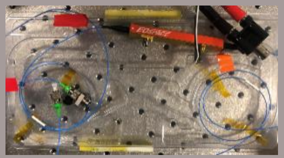
RF System



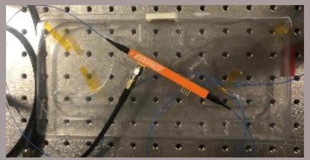
Laser (ECDL)

AOM

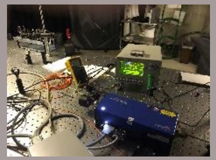
AM



PM



TA



Diagnostics