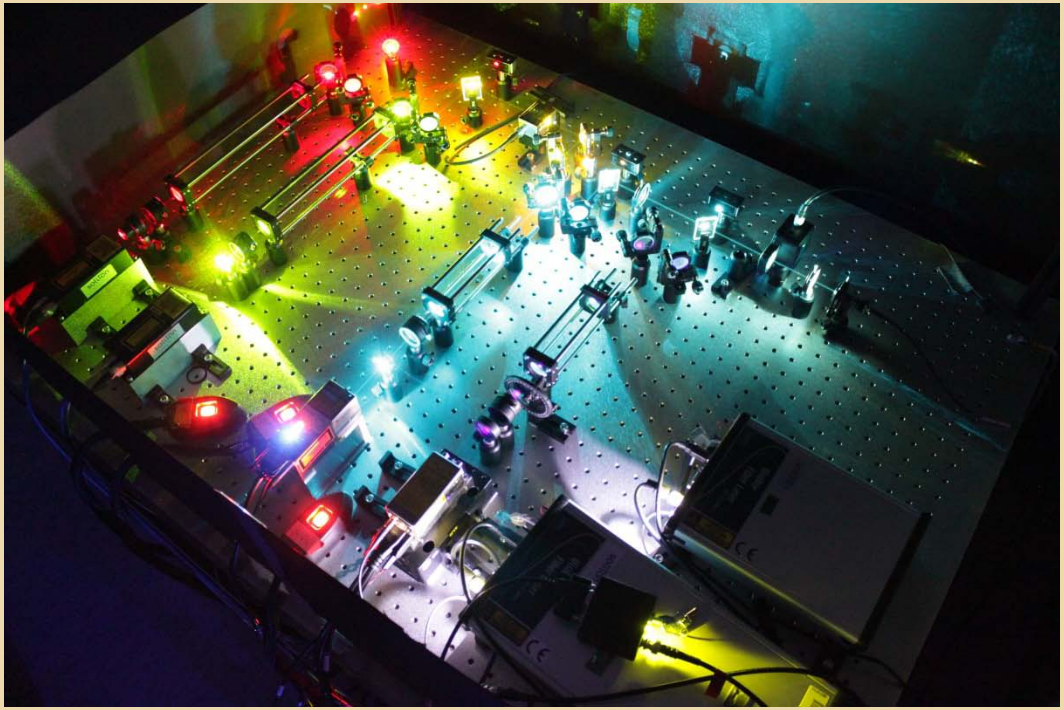
Building a Radio-Frequency Acousto-Optic Modulator Driver

Andrew Ballin



http://seamusholden.files.wordpress.com/2012/04/lasers.jpg

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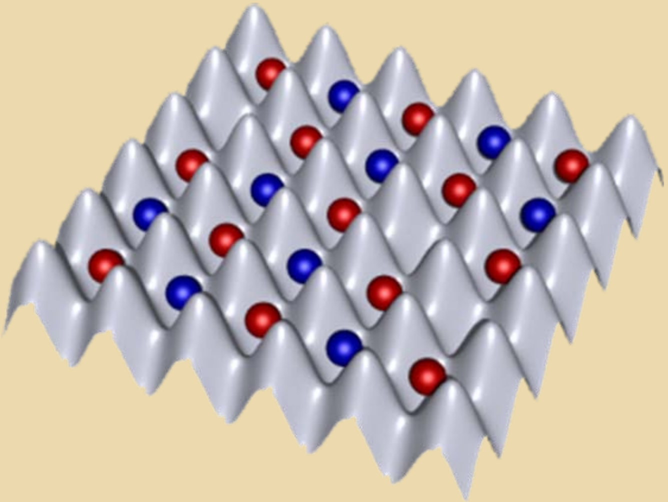
29 August 2013

Motivation

Condensed Matter Systems ⇔ Ultracold, optically trapped atoms

http://24.media.tumblr.com/tumblr_lh7ijnZGsv1qbtitpo1_500.jpg

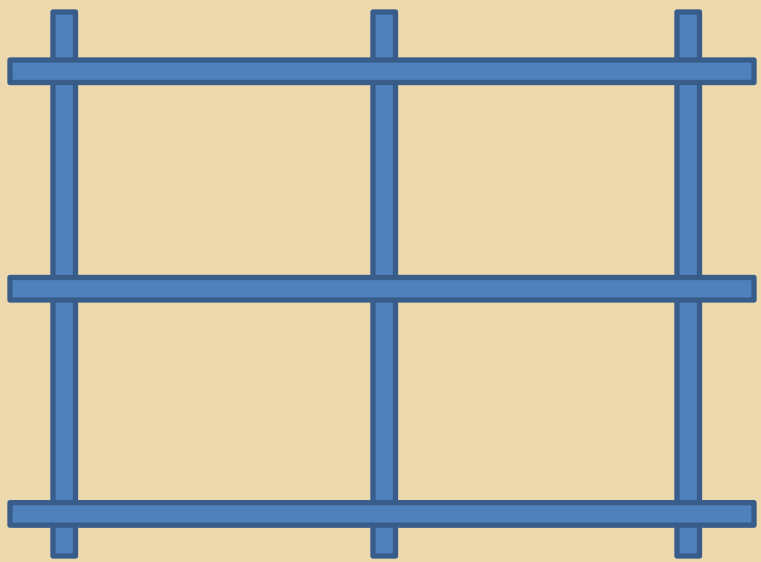


http://www.darpa.mil/uploadedImages/Content/Our_Work/DSO/Programs/Optical_Lattice_Emulator_(OLE)/OLE2[1].png

http://blogs.wavy.com/files/2010/01/cold-thermometer1.jpg

Cool:

Trap:



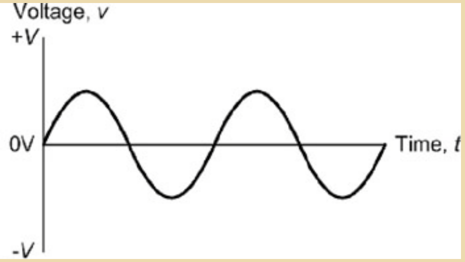
The Acousto-Optic Modulator (AOM) & Driver

- The AOM *driver* generates a sinusoidal voltage that drives (powers) the AOM

The AOM modifies:
- Frequency
- Intensity
- On-off state

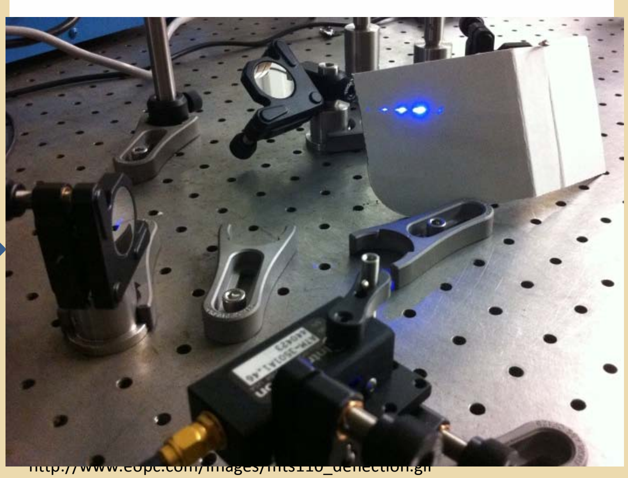
AOM driver:

Output signal



http://images.books24x7.com/bookimages/id_32210/fig1-105.jpg

AOM:



Goal: Build a More Practical Driver

- Bulky
- Expensive
- Long lead time

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- Bulky
- Expensive
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Source: http://www.rackmountsolutions.net/images/server-cabinet_enlarged.jpg

- Cheaper
- Space efficient
- Customized

Selecting the "Perfect" Parts

Data sheet/technical specifications:

power-one — *Changing the Shape of Power*

Linear Power Supplies Data Sheet

Input Specifications

PARAMETER	CONDITIONS/DESCRIPTION		MIN	NOM	MAX	UNITS
Input Voltage - AC (Note 1, 2)	Jumper selectable, shipped factory configured for	100 VAC Tap	87	100	110	VAC
	120VAC operation. All models must be externally	120 VAC Tap	104	120	132	
	fused for proper operation. Fuse ratings are marked	220 VAC Tap	191	220	242	
	on each unit. Consult factory for each unit's fuse requirements.	240 VAC Tap	209	240	264	
Input Frequency	AC input.		47		63	Hz
Line Regulation	Output voltage charge for a 10% line change: F case models.		-0.01		+0.01	%
	HAD12, HAD15.		-1.0		+1.0	
	Outputs with adjustable three terminal regulators.		-0.5		+0.5	
	All other models.		-0.05		+0.05	

NOTES: 1) Derate output current 10% for 50Hz operation.
2) Input voltage tolerance for 230VAC operation is +15%, -10%.

Output Specifications

PARAMETER	CONDITIONS/DESCRIPTION	MIN	NOM	MAX	UNITS
Output Adjustment	Minimum output adjustment range (Note 1).	-5		+5	%
Efficiency	5 volt outputs.		45		%
	12 volt and 15 volt outputs.		55		
	24 volt and higher outputs.		60		
Ripple and Noise (Note 2)	F case models.			3.0	mVPK-PK
	5 volt, 12 volt, and 15 volt models.			5.0	mVPK-PK
	All three terminal regulator outputs.			0.2	%PK-PK
	24 volt through 250 volt models.	3.0mVPK-PK plus 0.02% of output voltage, max			
Load Regulation	Output change for a 50% load change: F case models.	-0.02		+0.02	%
	HAD12, HAD15.	-1		+1	
	Outputs with adjustable three terminal regulators.	-0.5		+0.5	
	All other models.	-0.05		+0.05	
Transient Response	Recovery time, to within 1% of initial set point due to a 50% load change.			50	µs

NOTES: 1) **OUTPUT VOLTAGE ADJUSTMENTS:** Output voltage adjustments can be made to within ±5% of factory setting of nominal output voltage. Locate the "Vadj" potentiometer on the power supply PCB and use a screwdriver to adjust the output pot. The HAD12 and HAD15 3 terminal regulator outputs are not adjustable.
2) Full load, 20MHz bandwidth.

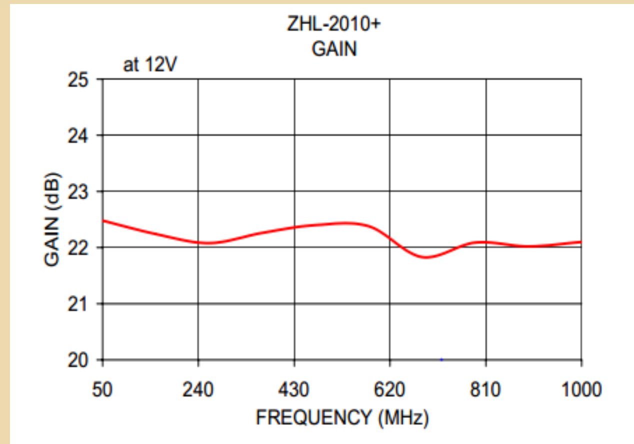
Safety, Regulatory, and EMI Specifications

PARAMETER	CONDITIONS/DESCRIPTION		MIN	NOM	MAX	UNITS
Agency Approvals	UL60950-1. CSA 60950-1 "cUL". EN60950-1. IEC60950-1.			Approved		
Dielectric Withstand Voltage	Input to output.		3000			VAC
	Input to ground.		1500			
Electromagnetic Interference	FCC CFR title 47 Part 15 Sub-Part B - conducted. EN55022 / CISPR 22 conducted. EN55022 / CISPR 22 radiated.		Compatible with system compliance to Level B.			
Leakage Current	Per EN60950	(264VAC)		23	50	µA

Interface Signals and Internal Protection

PARAMETER	CONDITIONS/DESCRIPTION	MIN	NOM	MAX	UNITS
Overvoltage Protection	Provided on 5 volt output units where indicated. Other outputs may use optional overvoltage protectors OVP-12 and OVP-24.	5.8		6.6	V
Remote Sense	Total voltage compensation for cable losses with respect to the main output. Provided on models where indicated.			250	mV
Overcurrent/Short Circuit Protection	Automatic current limit/foldback. Rated as a percentage of output power.	115	120	140	%
Master/Slave Operation	For parallel operation of up to 6 units. Master/slave pin provided on F case models only. Contact factory for application notes.				

http://www.mouser.com/ds/2/330/lin-238236.pdf



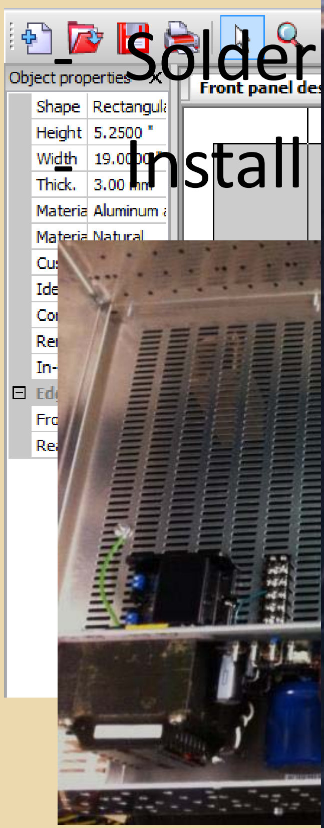
http://www.minicircuits.com/pdfs/ZHL-2010+.pdf

Calculations:

- Amplifier must provide 27dB of gain
- 4 drivers will require 4.8A @ 12V

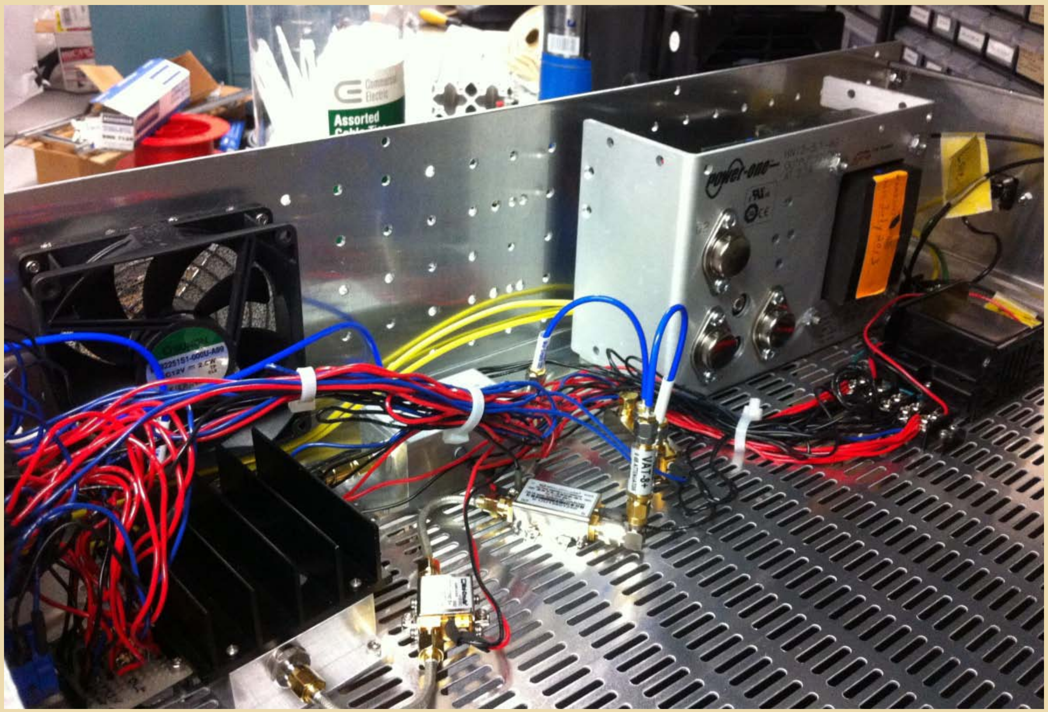
The Assembly

- Design the layout
- Machi
- Solder
- Install




The Final Product – Internals

Side view



Top view

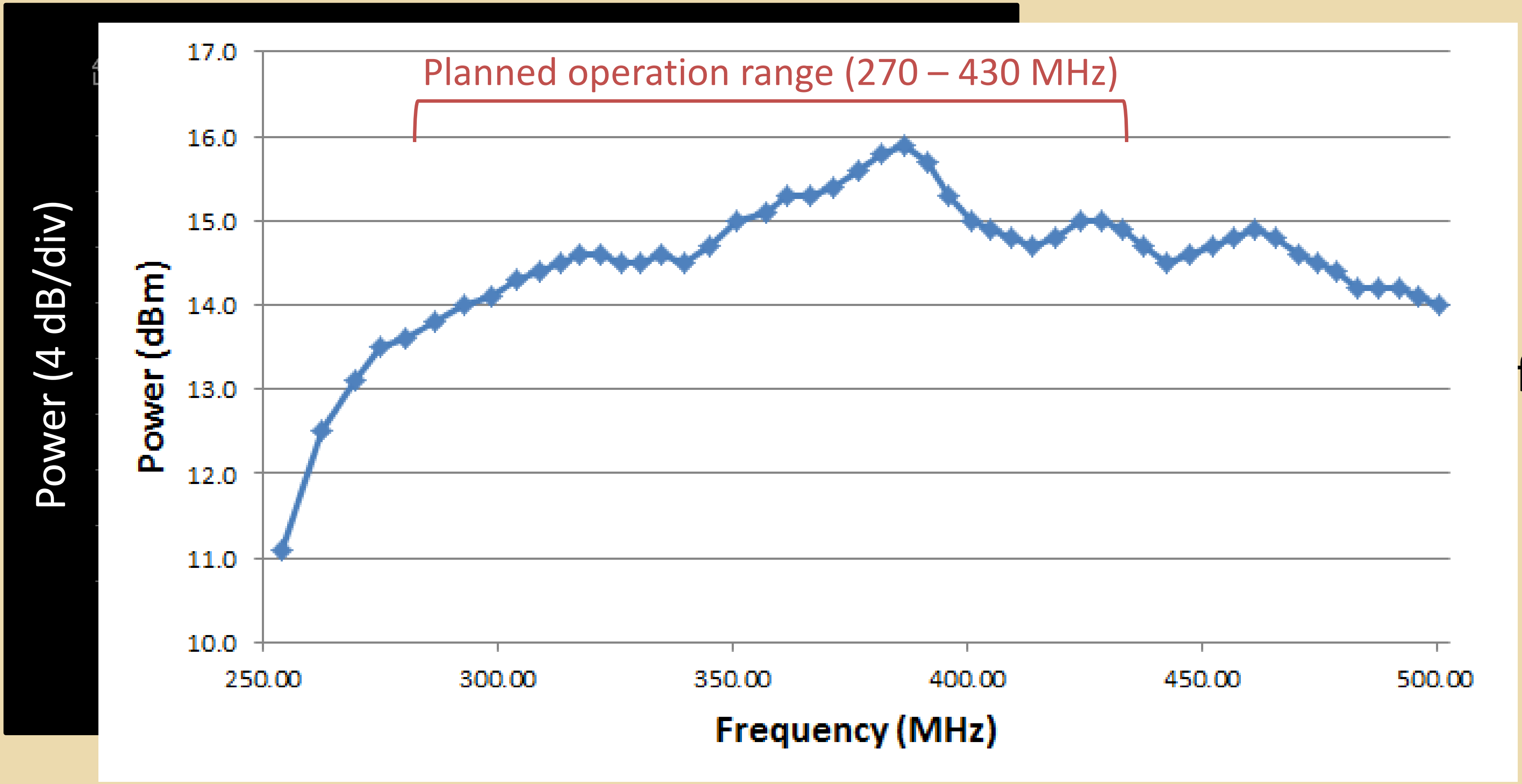
The Final Product – Interface

Results

It works!

Performance

Driver produce maximum power when generating a signal around its central frequency



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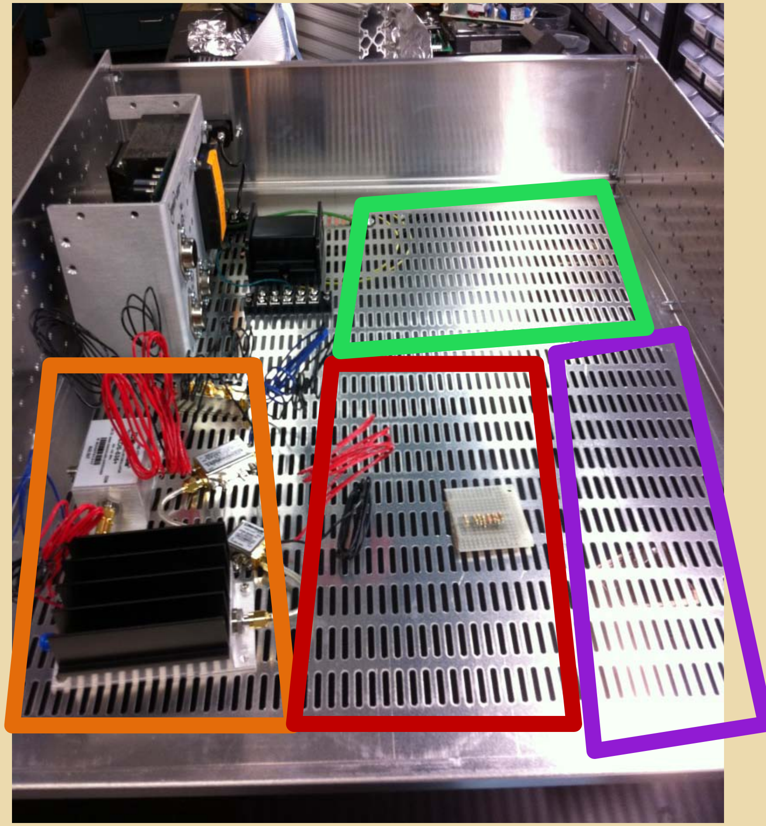
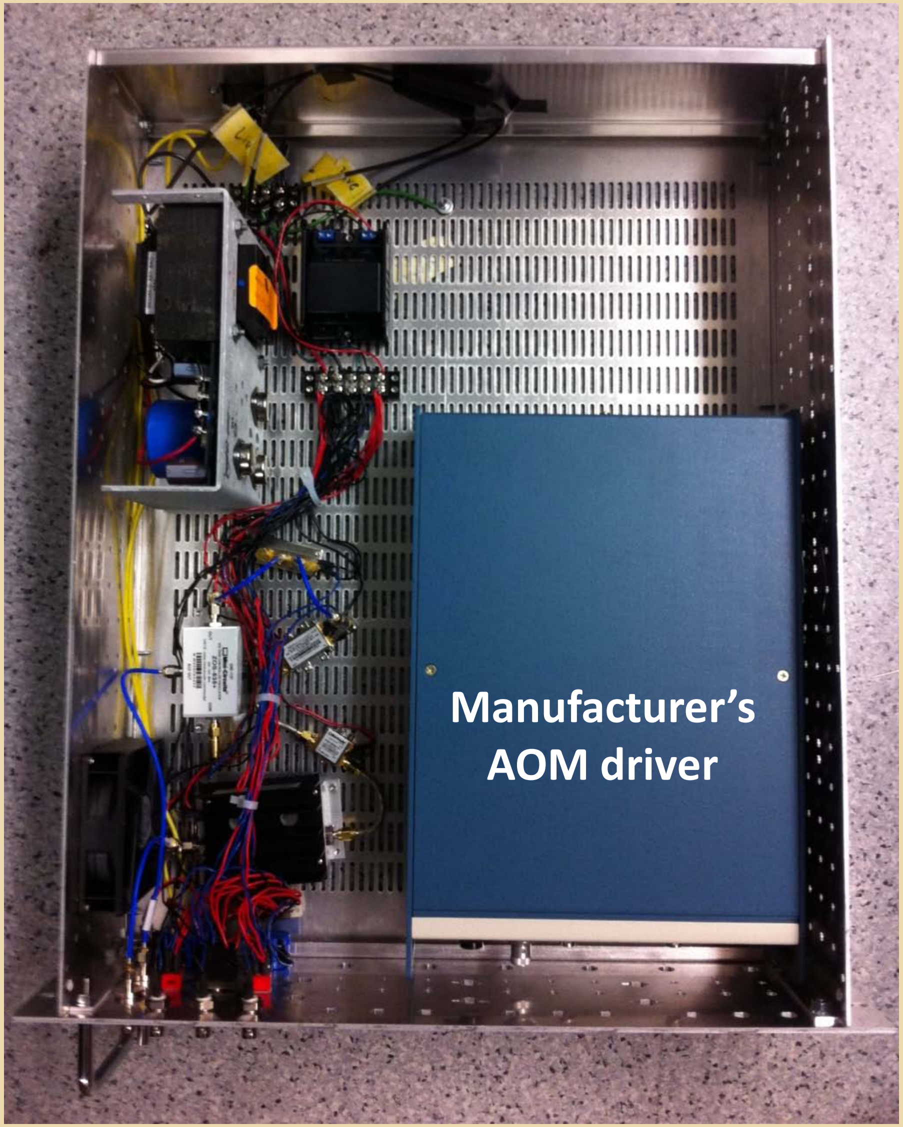
Achievements

- Reduced cost from $1,500 to $800 per driver (nearly 50% savings)
  - Will need appx. 30 drivers for all of our experiments (save about $20,000 total)
- Appears that chassis can suit 4 drivers



Achievements

Space efficient!



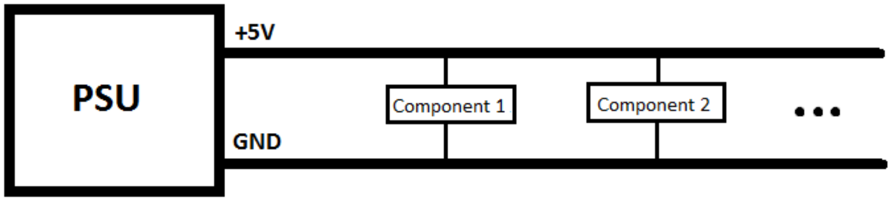
Achievements

- Documents my work
- Contains architecture for future AOM driver builds

weld lab wiki

The power supply (PSU):

In our case, the power supply is used to convert AC power from the wall to DC power at the voltages required to properly power the internal devices (listed above). The devices are connect to the power supply in parallel via voltage rails (wires that supply current at a certain voltage referenced to ground). The supply lead of a component is attached to the rail with the correct supply voltage, and the ground lead is connected to the ground/common rail. In other words, the component that we want to power bridges the supply rail and the ground rail, causing current to flow through the device. See the image below for an illustrative example.



There are two main types of power supplies: linear and switching. Switching power supplies are relatively cheap and can convert AC power to DC power with about 70-85% efficiency. The downside with switching supplies is that they produce relatively strong amounts of ripple (~120mV$_{p\text{-}p}$). On the other hand, linear power supplies have very low ripple (~5mV$_{p\text{-}p}$), but they are relatively inefficient (about 40-60% efficiency) and are generally more expensive.

Some power supplies have leads denoted as +/- S. These are the "remote sense" leads. Here are some good explanations of what these pins are used for:
- http://en.wikipedia.org/wiki/Sense_(electronics)
- http://forum.allaboutcircuits.com/showthread.php?t=69047

Important: if your power supply has the remote sense feature, the leads can only be attached across a single device! If you do not plan to use the remote sense feature, then you must connect these leads to the corresponding voltage lead (e.g. connect S+ to V+). Do NOT leave the sense leads open!

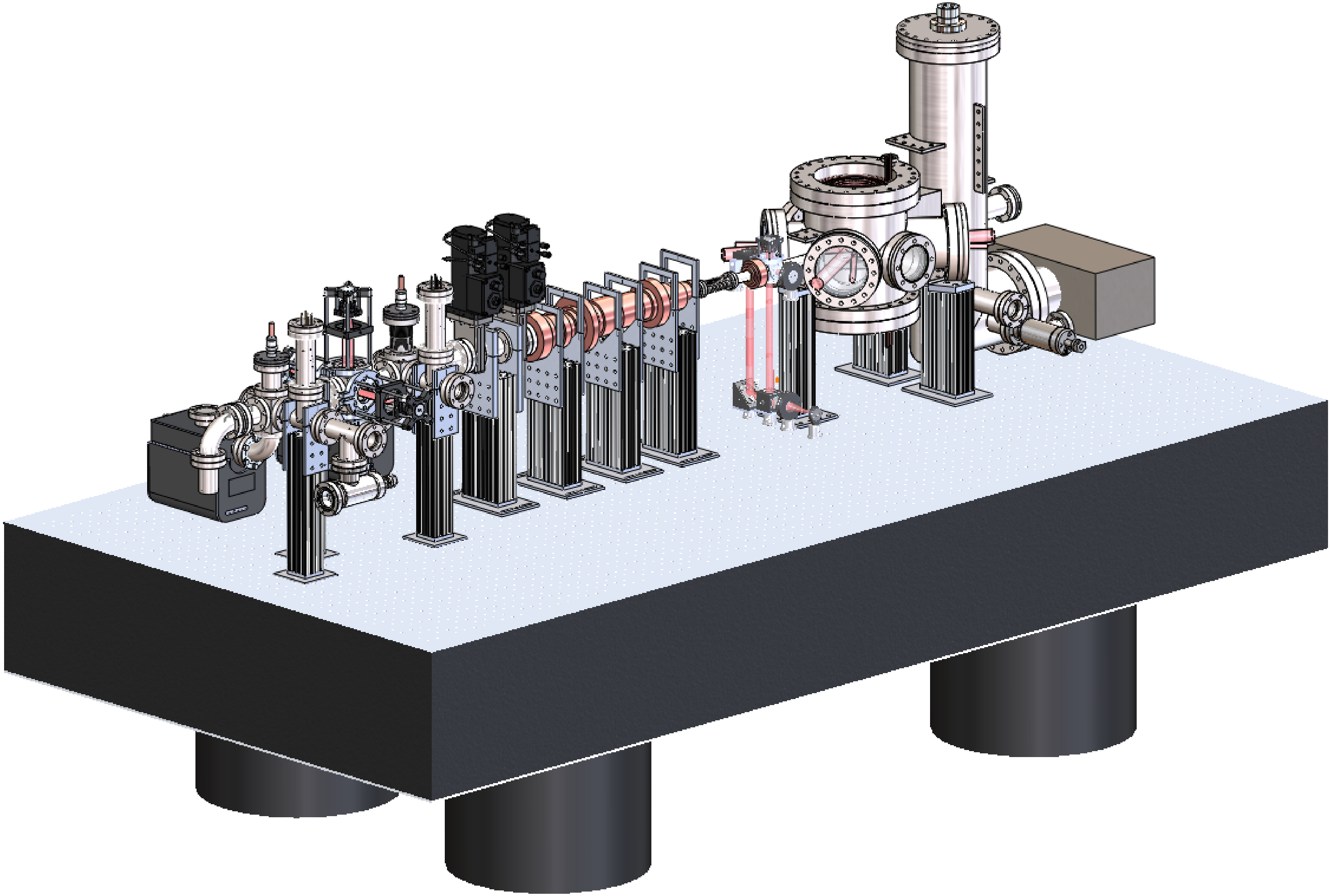
Additionally, here is a good explanation about the difference between earth ground and floating ground (F.G.):

Future Plans

- Improve upon current design for future drivers
- Share this architecture with other labs on campus

Acknowledgements

- Zach Geiger
- Dr. Vyacheslav Lebedev
- Professor David Weld
- Arica Lubin
- Kevin Moore



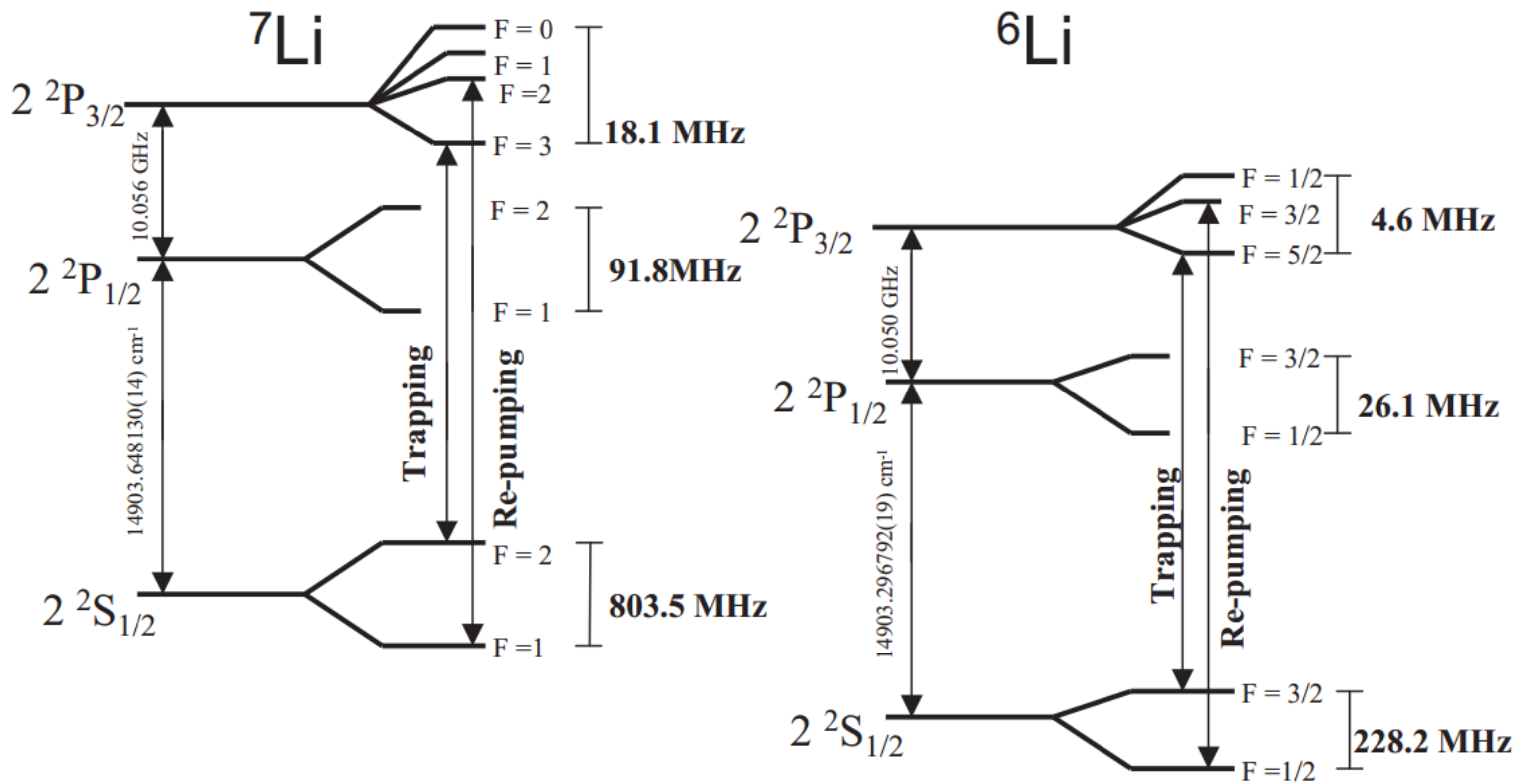
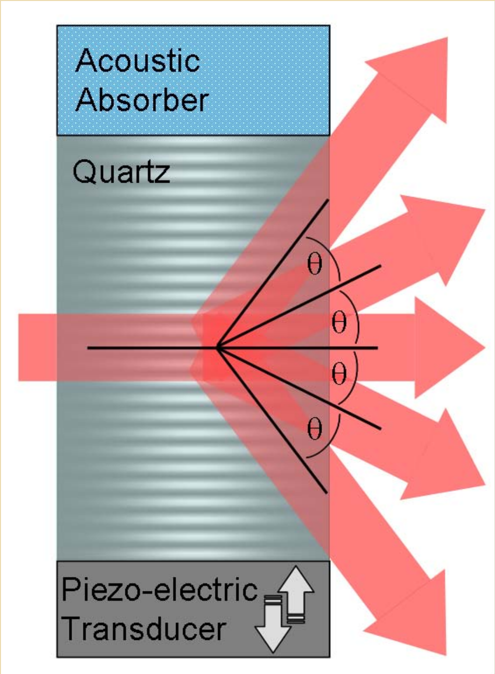
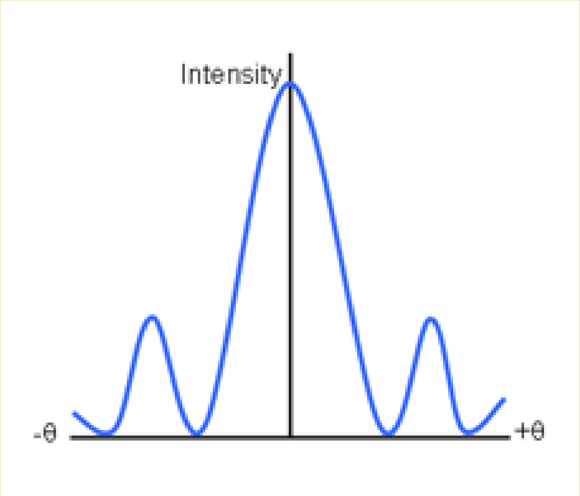


Figure 1.1 Optical transitions for ^{6}Li and ^{7}Li.

http://atom.stanford.edu/StreckerThesis.pdf



http://upload.wikimedia.org/wikipedia/commons/thumb/4/4d/Acousto-optic_Modulator.png/360px-Acousto-optic_Modulator.png



http://tap.iop.org/vibration/superpostion/323/img_full_46782.gif

AOM Driver Schematic