Pulsed Coherent Light: Cavity Dumping a Helium Neon Laser

Kevin Zheng, Martin Cohen, John Noé

Laser Teaching Center, Department of Physics and Astronomy

Stony Brook University

Welcome to the Laser Center

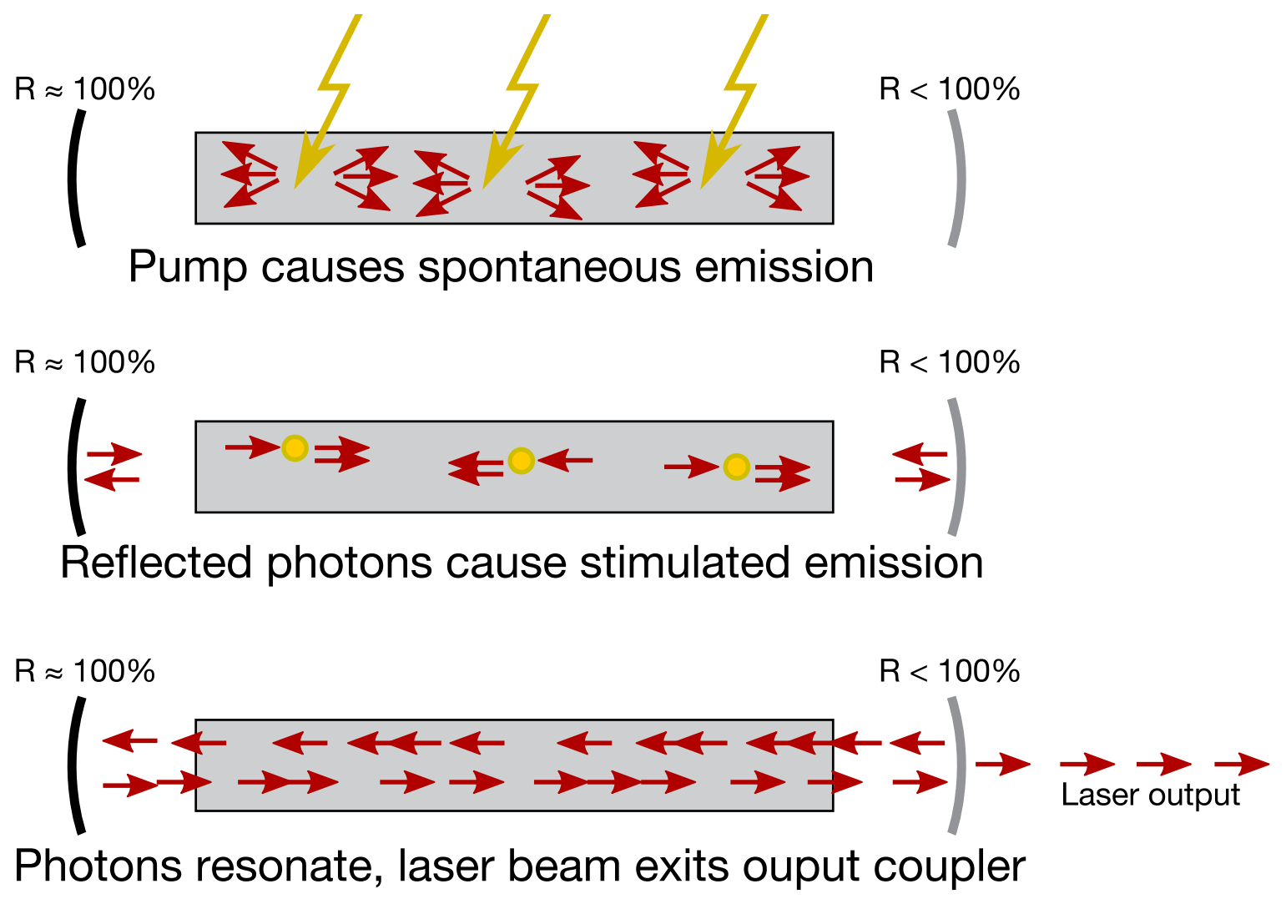
Overview

Lasers can operate in continuous wave (cw) or pulsed regimes. Pulsed lasers have high repetition rates, short pulse durations, and peak powers orders of magnitude greater than average power.

Continuous wave	Pulsed
Laser pointers	Telecommunications
Optical drives (CD/DVD)	Ultrafast spectroscopy
Laser pointers	Quantum computing
Barcode scanners	Laser eye surgery
Traditional laboratory lasers	Metal machining

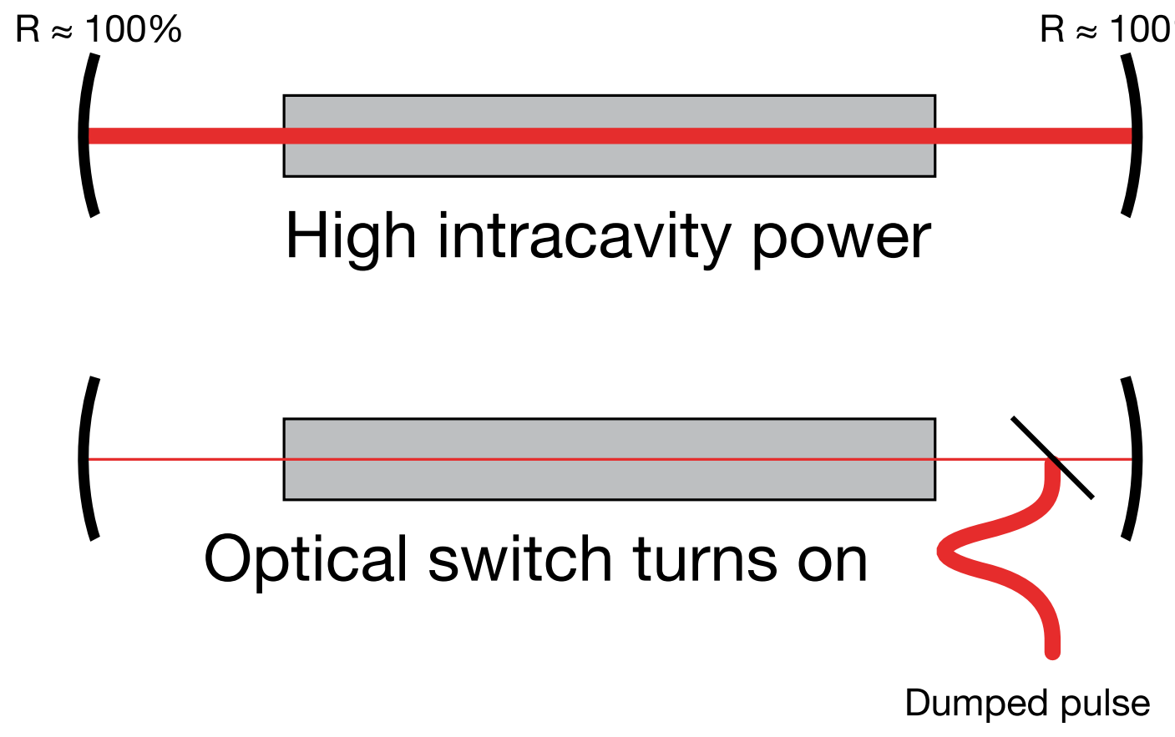
Techniques for creating a pulsed laser include cavity dumping, modelocking, Q-switching, and pulsed pumping. In this project, an open cavity helium neon laser is cavity dumped.

Laser basics

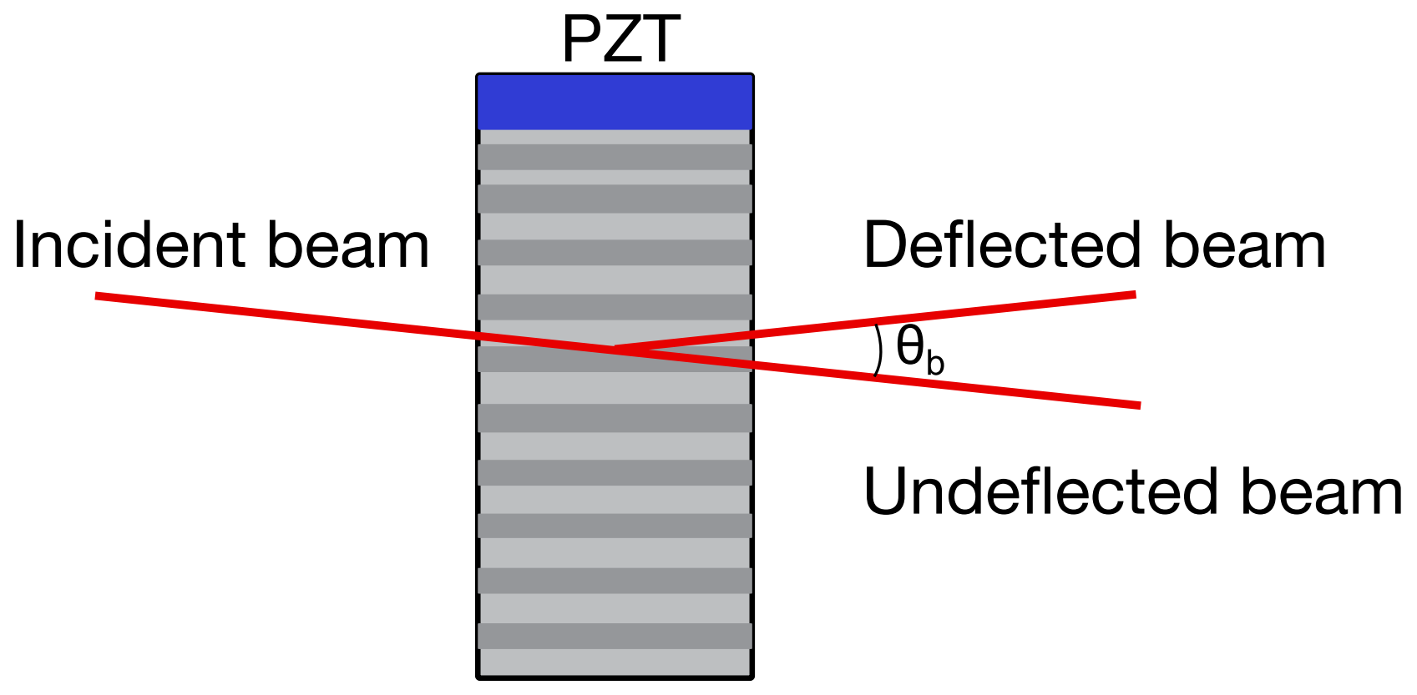


A laser cavity is a resonator for light. Spontaneous emission occurs when a gain medium is pumped, emitting photons in random directions. Some of these photons hit one of the mirrors and bounce back in the gain medium, causing stimulated emission. More photons bounce off the other mirror and back into the gain medium, causing more stimulated emission. The output coupler is less than 100% reflective, so a fraction of these resonating photons are emitted as the laser output beam.

Cavity dumping



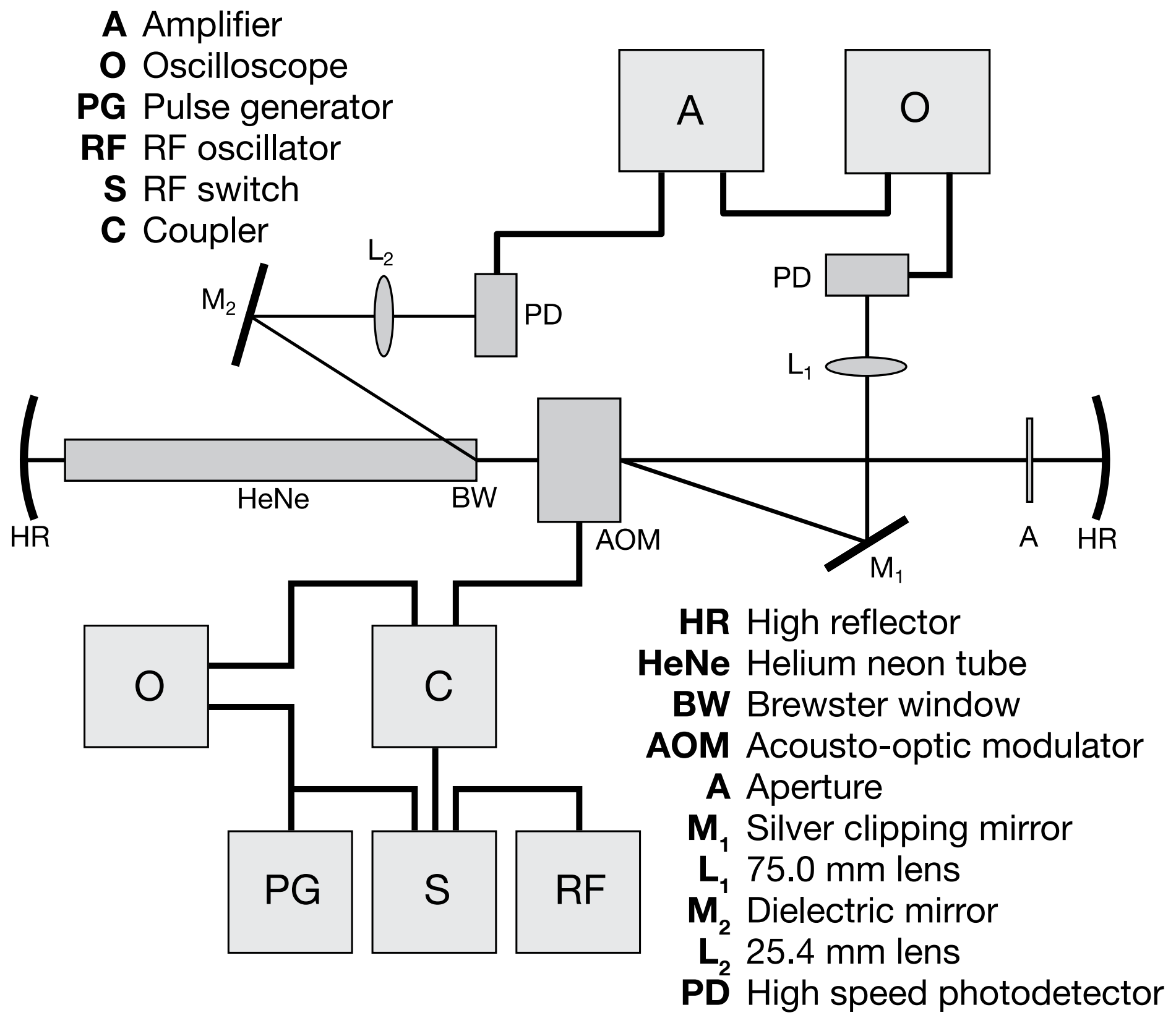
We replaced the output coupler with a high reflector to allow high intracavity power. When intracavity power peaks, an optical switch is gated on to extract the circulating power within a few round trips, creating a pulsed output. After extraction, the optical switch is gated off to allow intracavity power to build up again.



The optical switch is usually an acousto-optic modulator (AOM). A piezoelectric transducer bonded to a crystal sends acoustic waves through the crystal when excited by a RF signal. The spatially varying index of refraction create an optical grating which deflects the pulsed beam out of the cavity.

The repetition rate of the optical switch must be slow enough to allow the cavity to at least partially rebuild power. The RF must be gated on for long enough to allow a pulse to be dumped.

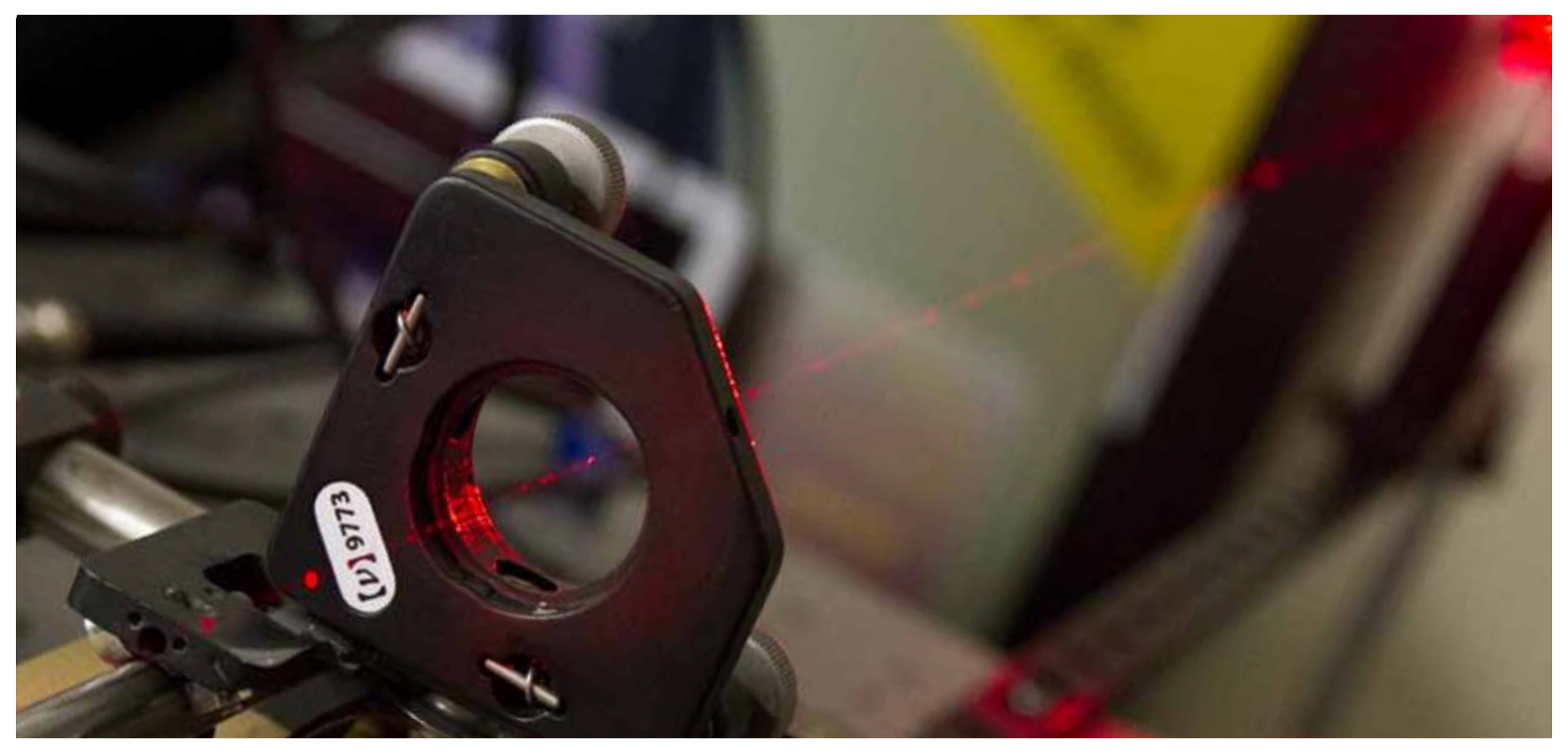
Setup



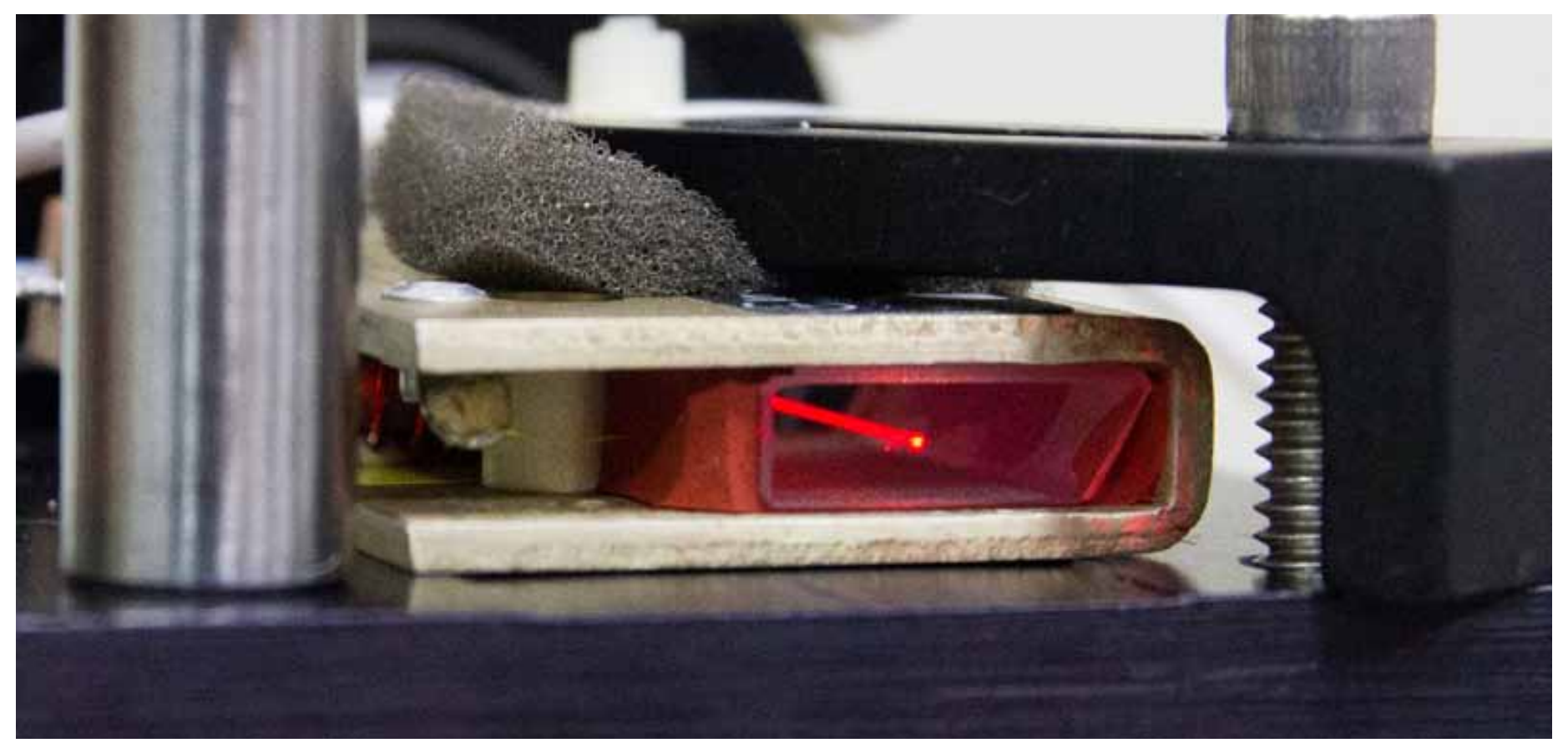
A Amplifier
O Oscilloscope
PG Pulse generator
RF RF oscillator
S RF switch
C Coupler

HR High reflector
HeNe Helium neon tube
BW Brewster window
AOM Acousto-optic modulator
A Aperture
M_1 Silver clipping mirror
L_1 75.0 mm lens
M_2 Dielectric mirror
L_2 25.4 mm lens
PD High speed photodetector

An acousto-optic modulator (AOM) is placed inside an open cavity helium neon laser near the beam waist as a high speed optical switch. When intracavity power is built up to a high level, the AOM is gated on to extract the power out of the cavity. After the power is extracted, the AOM is gated off to allow power to build up again.



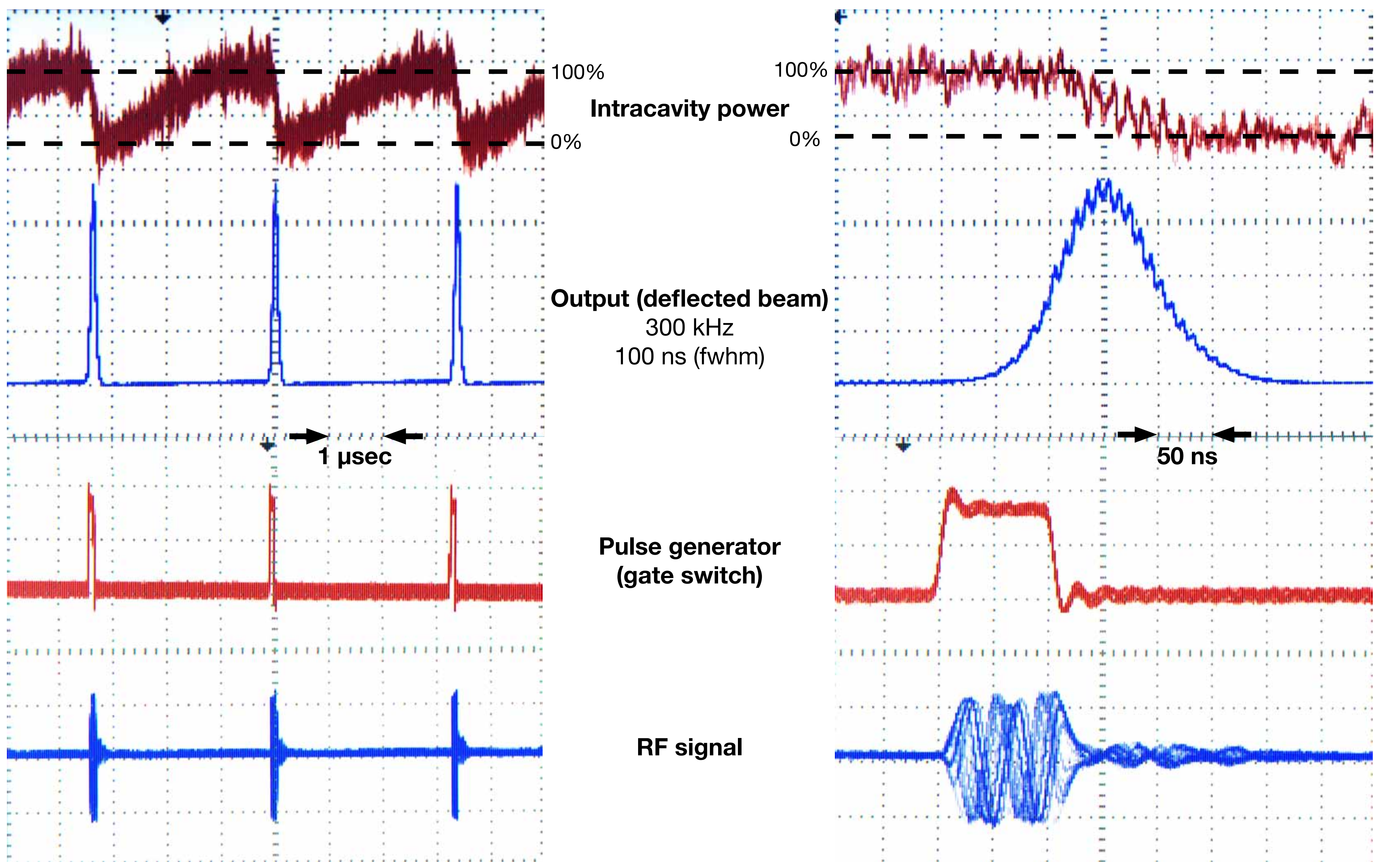
The high circulating power is clearly visible in a darkened room

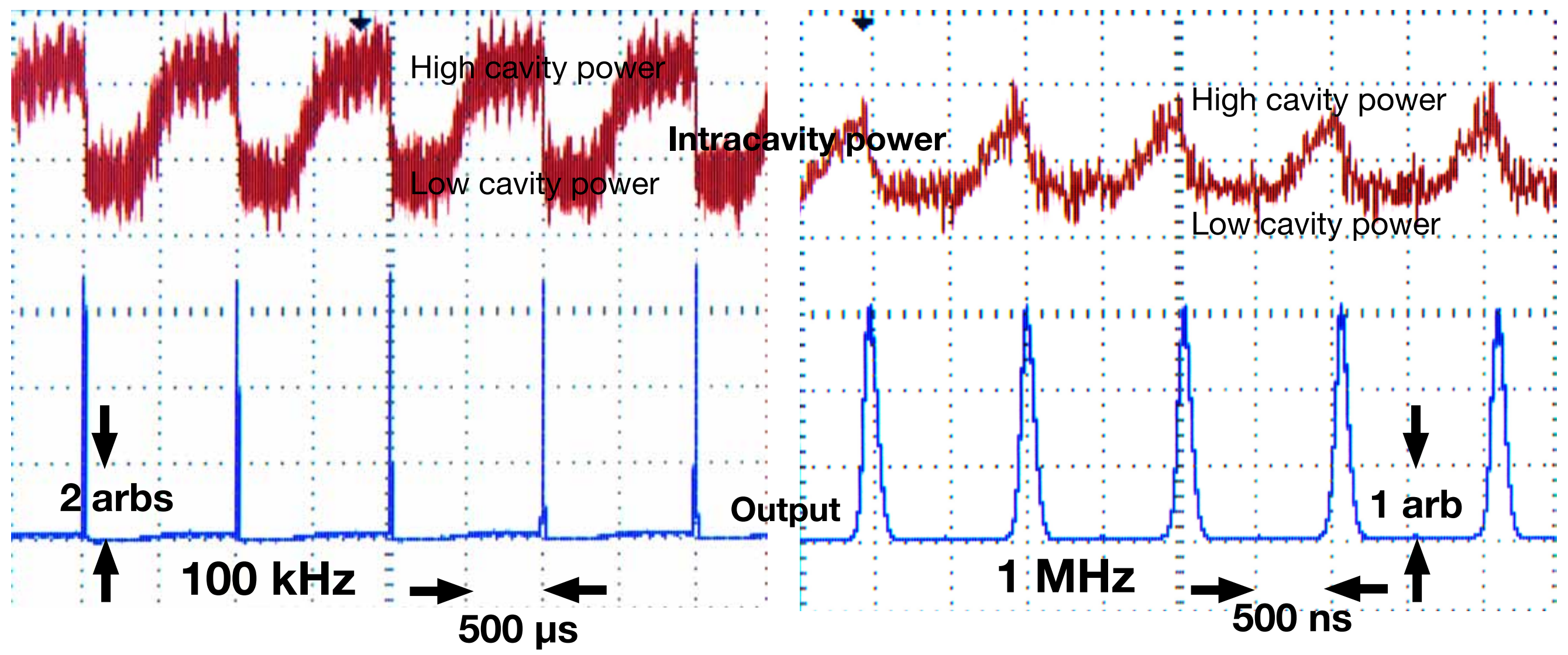


Scattering in the AOM medium accounts for much of the round trip losses

The extracted beam is monitored with a high speed photodetector. Intracavity power is monitored via the reflection off of the Brewster window of the helium neon tube.

Cavity dumped pulses





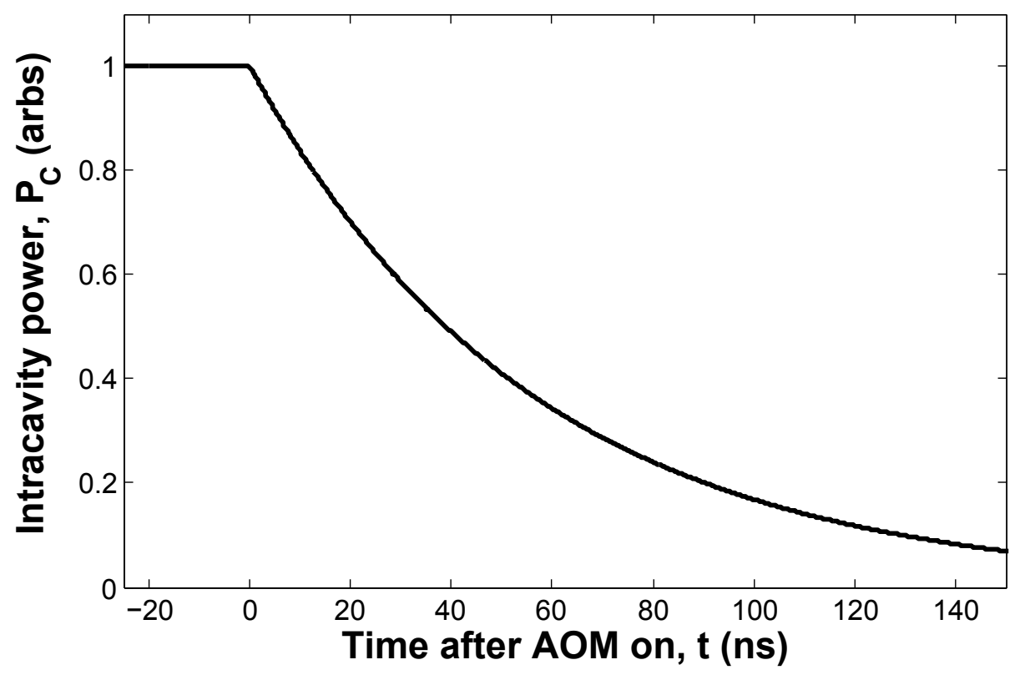
Unlike at 100 kHz, the cavity does not fully recover at 1 MHz. Peak power correspondingly drops. By changing the pulse duration, we can choose what level we want the cavity to recover to.

Intracavity power over time

Intracavity power as AOM is turned on at *t*=0:

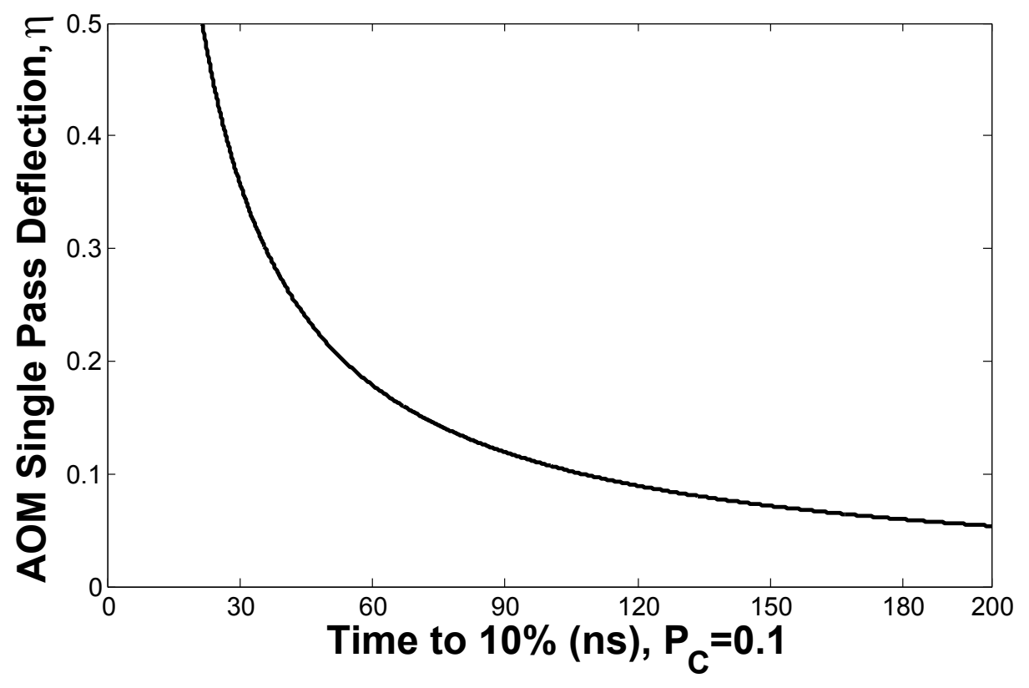
$$P_c = P_0 \exp\left(-\frac{2\eta t}{2L/c}\right)$$

L cavity length
P_0 initial circulating power
η one way AOM deflection



We have not yet developed a method to measure circulating power, so we use arbitrary units for P_c. We assume cavity power has built up to a maximum by t = 0.

Using the time it takes for intracavity power to drop to 10% ($P_C = 0.1$), we can calculate the single pass deflection of our AOM. The experimentally measured deflection efficiency is 8.3%. This is in fairly good agreement with our 100 ns pulses (expected: 10.8%).



Optical power limitations

- High losses of AOM medium (1.6% per pass)
- Slight Raman-Nath characteristics of AOM
- Low deflection ability of AOM
- Poor quality high reflector

Mode beating

The modulation in each pulse corresponds to longitudinal mode beating at about 100 MHz (10 ns period). This is in good agreement with the c/2L mode spacing in the cavity.

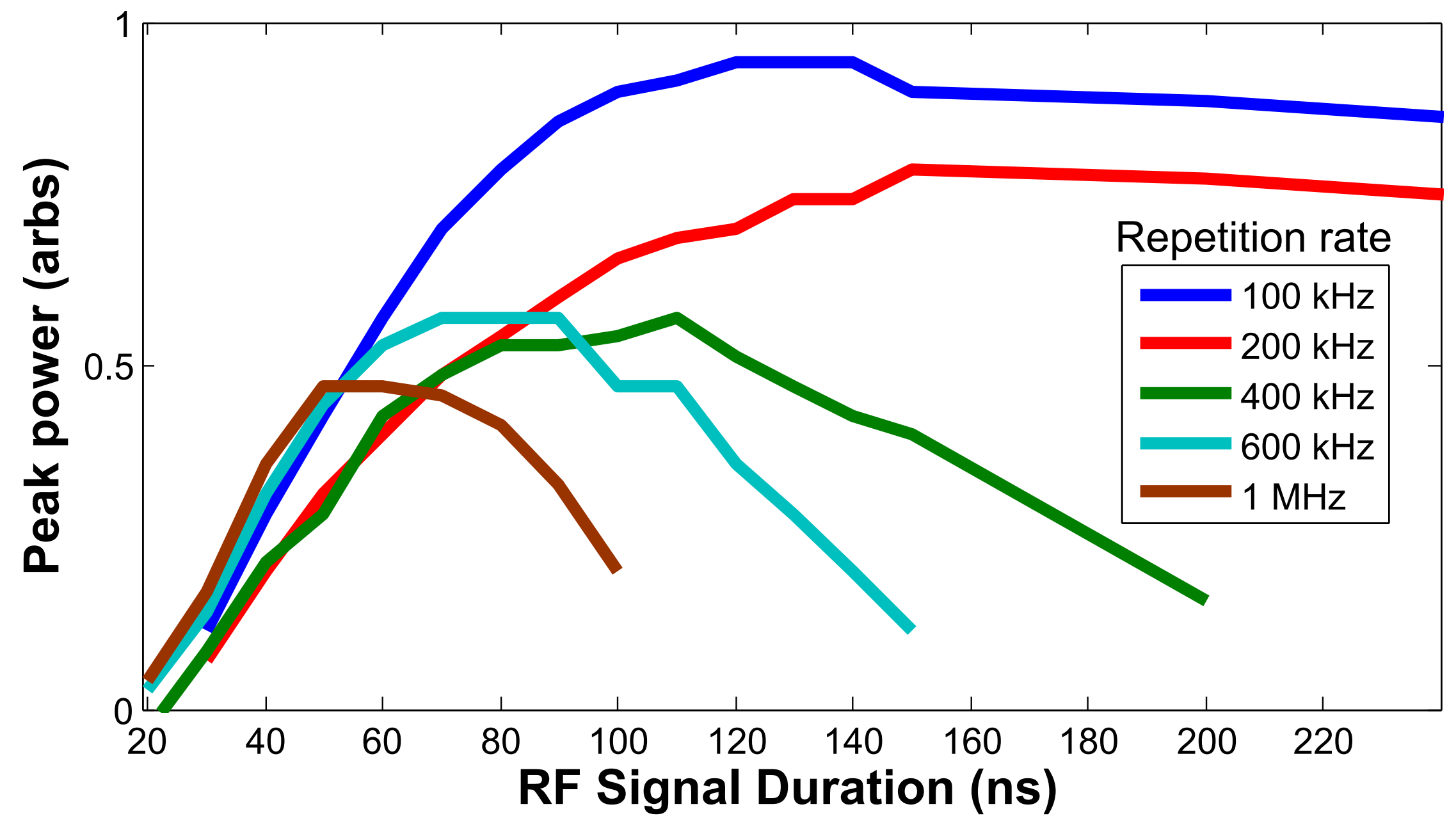
Generated pulses

Pulse duration	**100 ns**
Repetition rate	**Up to 1 MHz**
Average power	**0.016 mW**
Peak power	**2 mW**

Pulse shapes

The pulses are symmetrical rather than sharp rise/gradual fall (as predicted by the intracavity power curves) because of the rise/fall of the RF pulse, and the smooth beam cross section.

Peak power characteristics



Peak power per pulse is related to VHF signal duration and repetition rate. Output pulse duration stays constant at about 100 ns.

References

D. Maydan, "Fast modulator for extraction of internal laser power," J. Appl. Phys. 41, 1552–1559 (1970).

Simons Summer Research Program 2013

We would like to acknowledge Sam Goldwasser for providing key equipment. This work was supported by the Laser Teaching Center and the Simons Foundation.