Tune-up of 4k PSL 10-W laser S/N 108
7/11/01

Glen Truong, Floyd Keeth, Mark Guenther, and Rick Savage

INITIAL OPERATING PARAMETERS

Current: 22.15 amps
Temperature: DTs=22.7 C
Output power: 6.7 W measured with Ophir meter in path to PMC
Hours: 4405 on power supply S/N 107

LAYOUT AND NAMING CONVENTION

A photo of the optical layout is shown in Figure 1. The mirrors (M), Faraday isolators (F), thin-film polarizers (TFP) and lenses (SL or CL) are numbered sequentially in the beam propagation direction from the NPRO to the amplifier then from the amplifier to the laser output.

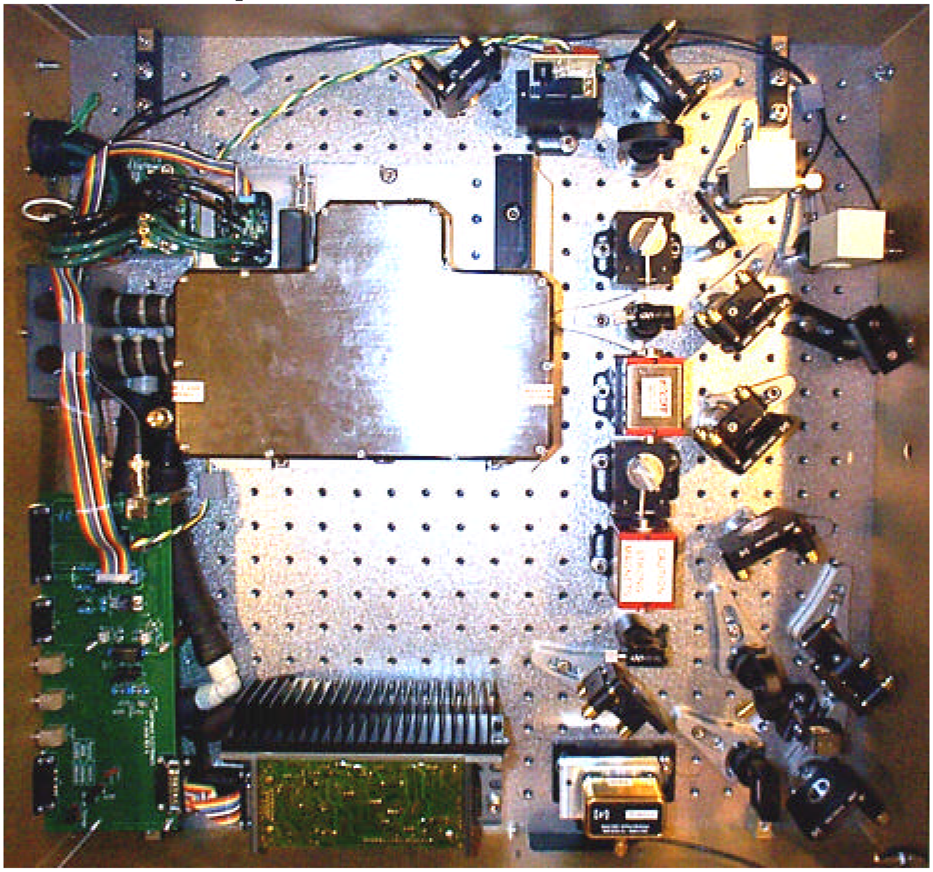

Figure 1 Optical layout of 126-MOPA.

ALIGNMENT THROUGH FARADAY ISOLATOR CHAIN

We noticed that the alignment of beam through the Faraday isolators was a bit off. We removed the spherical lens (SL1) from between the second (M2) and third (M3) turning mirrors after the NPRO and adjusted M2 and M3 while monitoring the beam location with an IR viewing card at the inputs to the Faradays.

Once the beam was well aligned, we inserted a beam pick-off mirror (PBS on a post) just in front of the first Faraday (F1) and sent the beam about .5 m away to a monitor. We used the Beam View camera as a monitor and noted the beam position before installing the lens between M2 and M3. We then adjusted the lens position to return the spot to the same position on the Beam View camera.

With the NPRO output at about 440 mW, we were only getting about 230 mW transmitted through the Faraday chain. We measured about 80 mW rejected by the first thin film polarizer (TFP1) and about 40 mW rejected by the second one (TFP2).

The rotation (yaw) of the TFPs was adjusted to maximize the transmitted power level (it might be better to minimize the rejected power). The transmitted power increased dramatically to about 87% (about 380 mW out of about 440 mW).

We rotated the half wave plates (HWP) before the Faraday cells to maximize the transmitted power (minimize the rejected power). There was no noticeable increase in transmitted power.

Using the Ophir meter, we measured 357 mW at the output of the NPRO (we measured 355 mW when Nergis and I installed the NPRO in May) and 304 mW at the shutter location (between M4 and M5). The throughput measured with the Ophir is thus about 85 %.

While we had the opportunity, we disconnected the cooling water flow to the NPRO.

ALIGNMENT INTO AMPLIFIER

After installing the alignment fixture at the entrance to the amplifier, we adjusted the two steering mirrors just before the amplifier (M4 and M5) for maximum throughput through the fixture. We used an IR viewer to visually inspect alignment at the input and output ends of the alignment fixture.

Now we switched on the amplifier while leaving the NPRO powered from the 126 supply. We turned the amplifier current down to 16 or 17 amps. We found the amplifier output beam reflected from TFP1 and moved main output beam steering mirrors (M6 and M7) to direct the main output beam to a power meter that can handle 10 watts. By adjusting M4 and M5 we increased the output power to about 2.5 W.

We then turned the amplifier current up to its nominal value, 22.15 amps. The output power at this current was about 7.5 watts. These powers are measured using Lightwave's Gentec meter. M4 and M5 were tweaked again and the maximum power achieved was about 8.2 watts. We also monitored the beam profile with Lightwave's Coherent Beam View camera mounted in the beam that is picked off for the reference cavity path.

AMPLIFIER CURRENT ADJUSTMENT

We increased the amplifier current from 22.15 amps to 24 amps and the output power increased to 10.5 W. The performance data sheet lists the maximum current as 25.75 A

AMPLIFIER TEMPERATURE SCAN

The 126-MOPA power supply was set to "service" mode by toggling the dip switch on the back of the power supply (second one from the left, labeled "SER") down then back up. This puts the supply in the service mode. We scrolled through the laser parameters until DT is displayed in the upper window. We then set the diode temperature to 18 deg by rotating the large knob on the power supply. The chiller then starts to bring the temperature down to 18 deg. The temperature displayed on the chiller controller and the power displayed on the Gentec meter were recorded.

The scan was going too slowly (about 1 deg in 15 minutes), so we moved the chiller closer to the laser and used a pair of ~10 ft. hoses to speed up the chiller response time. Glen Truong told us that the water flow should be input on the left connector and return to the chiller on the right side.

TEMP (deg C)	POWER (watts)
23.8	10.7
23.6	10.8
23.4	10.8
23.2	10.9
23.0	11.0
22.8	11.0
22.6	11.0
22.4	11.0
22.2	11.0
22.0	11.0
21.8	11.0
21.6	11.0
21.4	11.0
21.2	10.9
21.0	10.8

The temperature was set to 22.2 degrees. Because we were in the service mode, this will become the new default setting.

AMPLIFIER ALIGNMENT ADJUSTMENT

Now that the amplifier temperature is optimized, we touched up the amplifier alignment (M4 and M5) looking at both power and beam quality. The beam profile was significantly worse after changing the temperature and current. The output power did not increase significantly, but the profile was improved a lot. Glen still was not satisfied with the beam quality, so decided to adjust the longitudinal position of the spherical lens just upstream of M4 (SL2).

ADJUSTMENT OF MODE MATCHING INTO AMPLIFIER

The position of SL2 was marked with a felt tip pen. Before moving the lens the power was about 11 W and the beam circularity (on the Beam View display) was about 88 to 90 %. While watching the beam position and profile on the Beam View, the lens was moved about 1 cm toward the amplifier. The transverse position was adjusted and the alignment into the amplifier was optimized. The lens was then moved about 1 cm to the other side (away from the amplifier) from its original position and alignment was re-optimized.

The circularity parameter can be misleading. In practice, we are striving for a smooth circular or slightly elliptical beam as opposed to a beam that looks a bit square or rectangular. We are able to obtain a beam with about 11.3 W, but with a sort of rectangular profile with the long axis vertical. Aligning the beam into the amplifier such that we have a more circular beam yields only about 9.5 to 10 W.

NPRO BEAM PROFILE

We inserted a mirror to direct the beam transmitted through M2 to the Beam View camera. Glen said that the NPRO beam often does not look very good on the camera, but it looked exceptionally bad. We decided to remove the EOM from the beam path to see if it was causing the distortion. The beam moved slightly down when it was removed and the profile changed but still did not look very good. Figure 2 shows the profile of the beam picked off just after the NPRO with the camera about 3 ft. away.

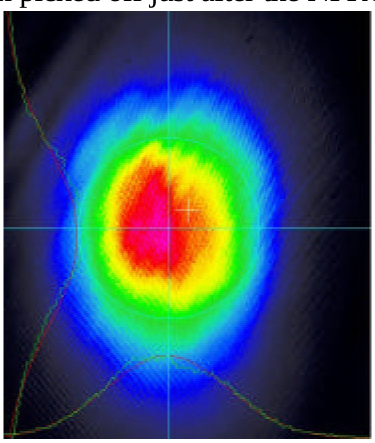

Figure 2 Beam directly from NPRO

There is some concern that the NPRO output window is damaged. Checking it would require removing the NPRO from the head and removing the Gold Box from the NPRO.

Based on Glen and Floyd's opinions that the beam quality is within the range of what is typical for the NPROs (albeit at the poor quality end of the spectrum) we decided to press ahead and do as best we can with the NPRO beam we have.

The profile of the beam transmitted through M2 is shown in Figure 3.

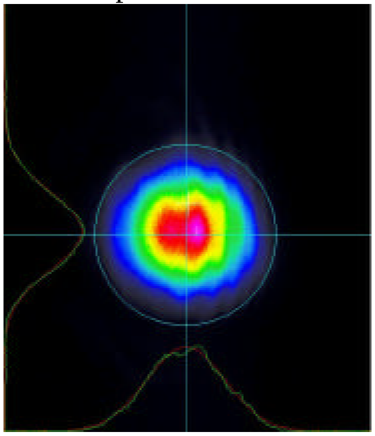

Figure 3 Beam transmitted through M2

We moved the camera about 10 inches farther away to see the effect of camera position. The profile in this location is shown inFigure 4

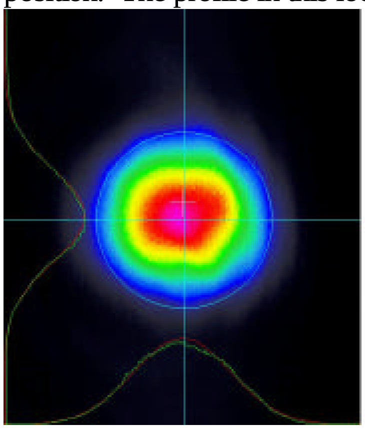

Figure 4 Beam transmitted through M2 with the camera moved about 10" farther away.

CYLINDRICAL LENS ADJUSTMENT

Glen moved the cylindrical lens mount longitudinally about 5 cm toward the amplifier (M1) the beam quality seemed to improve dramatically. This may be just a result of the camera location relative to the beam waist (Gouy phase). Figure 5 shows the beam profile after moving the cylindrical lenses. The EOM is still removed.

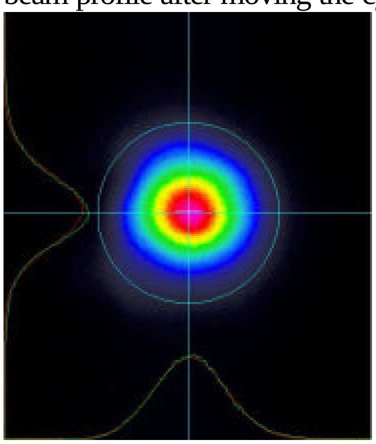

Figure 5 Beam transmitted through M2 after moving chlindrical lenses.

EOM INSTALLATION

Before installing the EOM, we marked (using the cursor) the beam position on the Beam View camera. Because the cylindrical lenses were moved away from the NPRO, we moved the EOM 1" farther away from the NPRO. We positioned the EOM by peaking the transmitted power. After this alignment, the beam was slightly higher and to the left of where it was without the EOM. Also, the beam reflected from the EOM was going back into the NPRO aperture. We adjusted the EOM mount so that the spot on the Beam View camera returned to its original vertical location but was offset to the left enough such that the beam reflected from the EOM was about 2 mm to the right of the NPRO output beam at the NPRO output aperture.

The beam leaving the NPRO is not very well centered in the output aperture. We removed the aperture to check centering. When replaced it we verified that the beam profile does not change, but it is pretty close to the side of the aperture.

The beam does not look nearly as good with the EOM installed. The profile of the beam transmitted through M2 with the EOM installed is shown in Figure 6

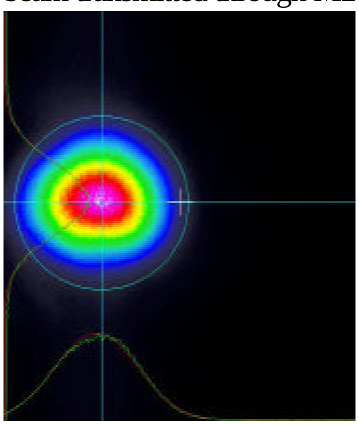

Figure 6 Beam measured after insertion of EOM.

EOM AMPLITUDE MODULATION MEASUREMENT

We measured the AM by installing a PDA55 (not modified) in the beam transmitted through M2 (the beam that we were using for the Beam View). A neutral density filter in front of the PD reduced the DC voltage level to 6.3 V. We drove the EOM with a sine wave from a SRS DS340 in the 50 ohm output impedance mode. The frequency was 10 kHz and the amplitude was 6 V_{p-p}. The measured RFAM spectrum is shown in Figure 7.

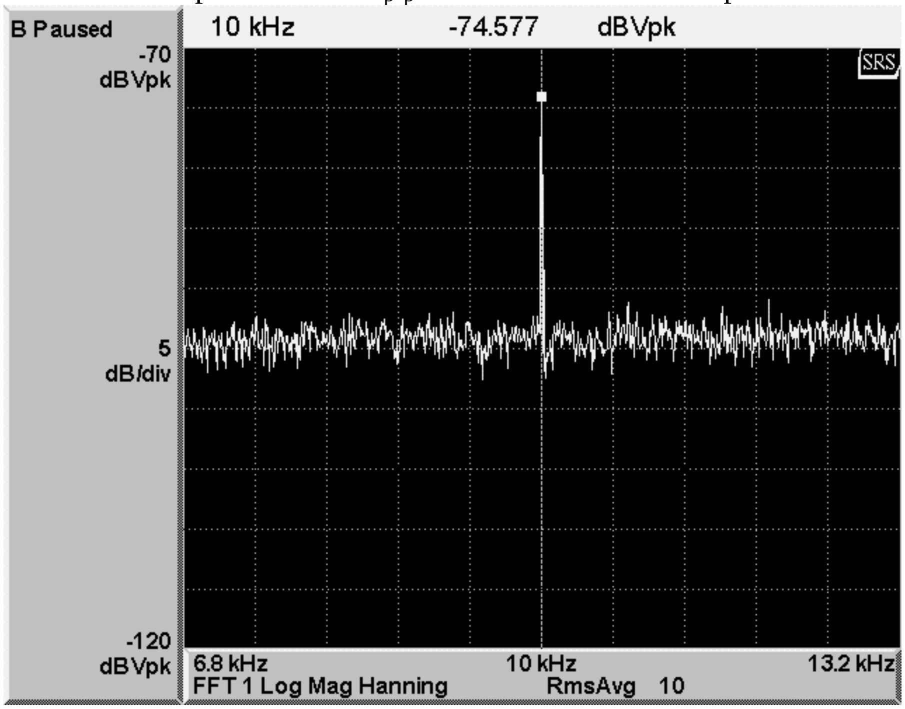

Figure 7 AM spectrum. The drive level was 6 volts peak-to-peak and the PD DC level was 6.3 V.

The level of AM is thus –74.6 dB divided by DC voltage level of 6.3 V or -16 db = -90.6 dB =3e-5 for 6 V_{p-p} drive. The EOM gives about 15 mrad per volt (mfg. spec.) so we have about 45 mrad for 3 Vpeak. The relative AM is thus about 6.7e-4 per radian.

NPRO POWER ADJUSTMENT

We decided to increase the NPRO power from about 44 mW (on Lightwave's Gentec meter) to about 500 mW. This should be accomplished via the pot accessible through a hole in the NPRO cover at the end the cables connect to. However, Nergis and I mistakenly adjusted the pot that is normally used to adjust the maximum current level (Imax) when we installed the NPRO in May. This pot is the one of the two closest to the cable connection end on the side of the NPRO. Glen adjusted this inside pot to about allow about 550 mW then used the pot accessible through the end cover to bring the power down to 500 mW.

NPRO PUMP DOIDE TEMPERATURE SCAN

By rotating the pot farthest from the cable connection end, the pump diode temperature was scanned from about 32 deg. C to about 30 deg. C. The NPRO power peaked at about 31 deg. C. Adjusting that inside pot changes the set point, so the pump diode will now run at this temperature.

MODE-HOP-FREE REGION SCAN

By adjusting the pot labeled TEMP, accessible through the cover at the cable connection end, the laser temperature set point was scanned to map out the mode-hop-free regions. Lightwave uses an etalon, lens, and CCD camera arrangement to monitor the mode hops. We could probably use the Coherent scanning Fabry-Perot cavity. As the pot is turned, the voltage appearing on pins 2 an 4 (reading from the top on the row of 8 pins on the right on the circuit board near the connector end of the NPRO) is recorded when a mode hop occurs. The conversion is 1 mV per deg. C.

HIGH	LOW
53.2	51.4
50.9	48.9
48.3	46.2
45.6	41.8
40.9	37.1

The middle of the mode-hop-free region closest to 45 deg. C is chosen, so the nominal laser crystal temperature was set at 43.7 deg. C.

When the connections for the NPRO were switched back over to the MOPA supply, the voltages associated with the NPRO temperature changed. What was 43.7 deg. C with the 126 power supply became 44.9 with the MOPA supply. Glen and Floyd checked that we were still in the middle of a mode-hop-free region. It is from 42.7 to 47.1 when powered by the MOPA supply.

FINAL ALIGNMENT INTO AMPLIFIER

With the amplifier temperature, NPRO diode temperature and NPRO crystal temperature optimized, we verified that the beam is passing cleanly through the Faraday isolator chain and the that the power in the beams rejected by the TFPs is still small. We then adjusted M4 and M5 to optimize power AND beam quality. We were able to achieve 21 watts with a rectangular-looking beam. Glen went for beam quality rather than quantity and we ended up with 10.0 watts (on the Lightwave meter) with a beam as shown in Figure 8.

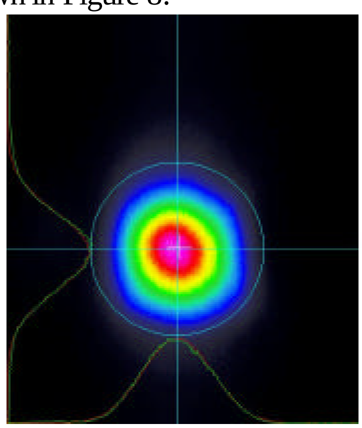

Figure 8 Final beam profile. Measured in reference cavity beam path.

The associated beam parameters are

Sample 177 - Jul. 12, 2001 - 03:53:27 PM	
Peak (X,Y)R [pixel]	(112.0, 137.0) 177.0
Centroid (X,Y)R [pixel]	(115.4, 136.2) 178.5
Peak % Resp. [%]	98.0
Total Rel. Power [mW]	1.207
Aper. Diameter 86.5% [mm]	2.234
Knife Edge 84.0% [mm]	1.813, 2.138
Ellipticity	
Circularity	0.885
Gaussian Fit 86.5%	
Coefficient	0.961, 0.967
Centroid [mm]	1.948, 2.705
Peak Intensity [digital]	246.7, 239.2
Diameter [mm]	1.620, 1.776
Roughness of Fit [%]	6.8, 4.0
Aperture Uniformity	
Min, Mean, Max [digital]	7.0, 82.0, 250.0
Sigma, RMS [digital]	61.5, 103.1
% Power in Aper. [%]	83.0

The powers measured with the Ophir high-power head are 454 mW at NPRO output (LTW got 500 mW after the EOM) and 361 mW at the input to the amplifier, between M4 and M5 (LTW measured 420 mW). We measured 9.6 watts in the main beam in the path to the PMC (LTW measured 10.0 W) with the Ophir head. With the large Scientech head in the same location, we measure 9.0 watts.

Evaluation of 126 MOPA S/N 107

We decided to take at look at the 10-W laser in the optics lab. We had removed the current shunt, so we connected the amplifier power cables without the shunt and reduced the operating current from 25.8 to 25.55 A. The output power measured with LTW's Gentec meter was 10.5 watts and the beam profile (measured by placing the Beam View in the sample beam) was as shown in Figure 9.

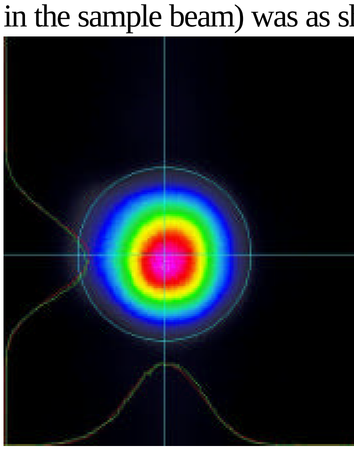

Figure 9 Main output beam from 126-MOPA laser S/N 107

We also looked at the beam from the NPRO by directing the beam transmitted through M2 out the sample beam window to the Beam Scan, see Figure 10.

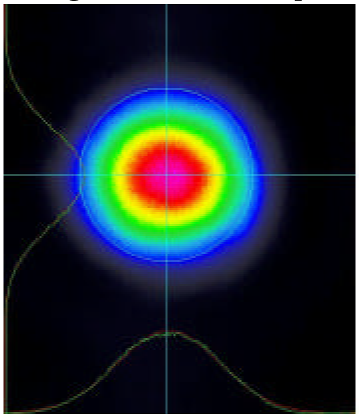

Figure 10 Beam from NPRO transmitted through M2.

The beam parameters are:

Sample 037 - Jul. 12, 2001 - 06:16:54 PM

Peak (X,Y)R [pixel]	(116.0, 98.0) 151.9
Centroid (X,Y)R [pixel]	(111.8, 103.3) 152.2
Peak % Resp. [%]	93.7
Total Rel. Power [mW]	1.893
Aper. Diameter 86.5% [mm]	2.352
Knife Edge 84.0% [mm]	2.361, 2.308
Ellipticity	
Circularity	0.937
Gaussian Fit 86.5%	
Coefficient	0.958, 0.968
Centroid [mm]	1.881, 1.963
Peak Intensity [digital]	240.7, 234.9
Diameter [mm]	2.373, 2.175
Roughness of Fit [%]	6.3, 3.8
Aperture Uniformity	
Min, Mean, Max [digital]	33.0, 121.0, 239.0
Sigma, RMS [digital]	53.9, 132.6
% Power in Aper. [%]	77.6

Installation of EOM in 10-W main output beam

We installed an EOM (New Focus Model 4102) in the main output beam. We plan to do a long-term exposure test. We measured the beam parameters before installing the EOM by looking at the transmission through a CVI Y1 mirror. Figure 11 shows the beam before installing the EOM.

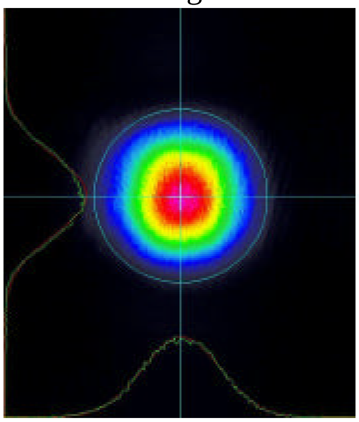

Figure 11 SN 107 main output beam before installing EOM.

We then installed the EOM in the output beam and verified that the spot had not moved significantly also that the reflected beam was not going directly back into the laser. The beam profile after inserting the EOM is shown in Figure 12.

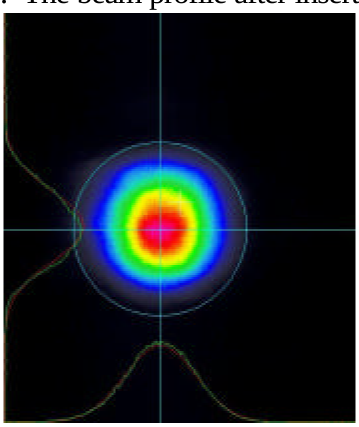

Figure 12 SN 107 main output beam with EOM installed.

The beam parameters are:

Sample 077 - Jul. 12, 2001 - 07:34:18 PM

Peak (X,Y)R ± [pixel]	(-16.0, -15.4) 22.2
Centroid (X,Y)R ± [pixel]	(-13.1, -12.6) 18.2
Peak % Resp. [%]	92.2
Total Rel. Power [mW]	1.002
Aper. Diameter 86.5% [mm]	1.842
Knife Edge 84.0% [mm]	1.736, 1.822
Ellipticity	
Circularity	0.988
Gaussian Fit 86.5%	
Coefficient	0.965, 0.944
Centroid [mm]	1.786, 2.435
Peak Intensity [digital]	224.7, 232.1
Diameter [mm]	1.647, 1.632
Roughness of Fit [%]	6.4, 10.6
Aperture Uniformity	
Min, Mean, Max [digital]	6.0, 73.0, 235.0
Sigma, RMS [digital]	60.7, 95.0
% Power in Aper. [%]	88.4

The output power measured with our Gentec meter was 10.1 watts. The long-term exposure testing of the EOM began on 7/13/01 at about 8:00 PM.