An Introduction to the New Focus TA-7600 VAMP™ Tapered Amplifier

1. Introduction

The output power of an external cavity diode laser (ECDL) can often range from 10-100+ mW, depending on such factors as the capability of the laser diode, the external cavity optics and their configuration, and the drive electronics. However, some applications require much higher laser power and in these cases an optical amplifier can be used to directly amplify the ECDL output. The amount by which the ECDL output is amplified is often referred to as the *power gain* and is usually measured in units of decibel (dB). The power gain of an optical amplifier which takes a seed power, P_{seed}, to give an amplified output power, P_{out}, can be obtained using the equation below. For a hypothetical optical amplifier which takes a seed power of 10 mW to give an output power of 1 W, the power gain has a magnitude of 20 dB.

$$Power\ gain\ [dB] = 10 \mathrm{x} \mathrm{Log}_{10}\left(\frac{P_{seed}}{P_{out}}\right)$$

Depending on the ECDL wavelength, different optical amplification techniques can be used. In the near IR and short wavelength IR, rare earth doped fiber amplification is often used. Here, the gain medium is a glass optical fiber that is doped with rare earth ions of Er, Nd, or Yb. By first optically pumping the ions, a laser beam propagating down the fiber can subsequently be amplified by way of stimulated emission. In Raman or Brillouin scattering amplification the gain medium is usually an optical fiber but can be a crystal or cell filled with gas or liquid. For applications in the visible and near IR regions, tapered semiconductor diodes are often used as the gain media. And as we will see, the tapered semiconductor diode is at the heart of the New Focus TA-7600 VAMP™ Tapered Amplifier system.

This Note begins with a brief introduction to optical amplification by way of the tapered semiconductor diode. We then concentrate on the New Focus TA-7600 VAMP Tapered Amplifier (VAMP TA) system with an emphasis on its design features and ease-of-use. In the last section, we look at how to implement the VAMP TA system in amplifying the output of a seed laser and will see how such seed laser parameters as wavelength and power can ultimately affect its performance.

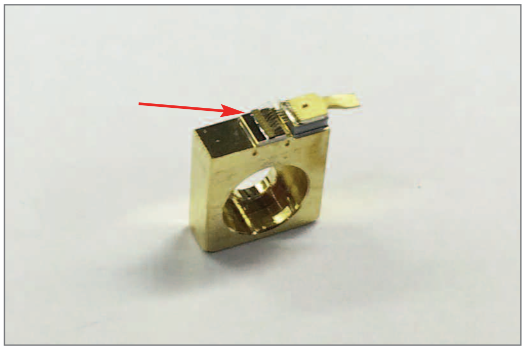

Figure 1. Tapered amplifier chip on standard C-mount. Arrow points to chip.

2. What is a Tapered Amplifier?

As mentioned above, a tapered amplifier can be used to optically amplify milliwatt radiation from a seed ECDL into watts – all while preserving the spectral properties of the seed (wavelength, linewidth, polarization, etc.). At the heart of any tapered amplifier system is the amplifier chip (an example is shown in Fig. 1), and central to the chip itself is the tapered gain region. This tapered gain region, with an output facet much wider than the input facet, is often made of a III-V semiconductor, such as GaAs. By electrically pumping this region an inversion in the carrier population can be established. Both facets are usually anti-reflection coated. Thus, a beam of radiation of suitable wavelength and polarization subsequently directed into this gain region would experience amplification due to stimulated emission resulting from electron-hole recombination.

In a Master Oscillator Power Amplifier (MOPA) configuration an external laser is used to provide the seed radiation to the tapered amplifier system. An example schematic of a MOPA setup is shown in Fig. 2. In this example, a New Focus Vortex™ Plus is being used to seed a VAMP TA represented by the dashed lines. As shown in the figure, internal optics shape and guide the beam: Lens 1 helps focus and direct the seed beam into the diode. The amplified output is then collimated by lenses 2 and 3 and passes through a single-stage isolator, which prevents light from being fed back into the diode.

TA-7600 VAMP™ Tapered Amplifier

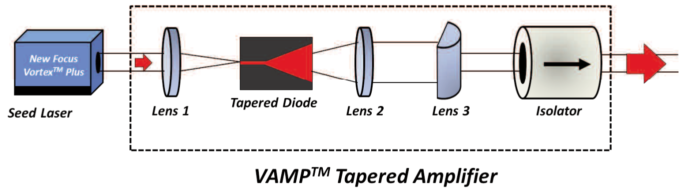

Figure 2. Optical amplification via MOPA configuration. Seed New Focus Vortex™ Plus laser seeds VAMP™ TA, represented by dashed lines. Some internal elements are shown, albeit not to scale. Input and output optical fibers not shown.

Figure 4. Easy-to-use front panel of the TA-7600-LN Tapered Amplifier controller offers full controls over VAMP TA system.

3. Design Features of the New Focus VAMP TA System

A three-dimensional rendition of a VAMP TA head is shown in Fig. 3 along with callouts to some key features. On the left is the FC/APC input fiber connection (a) standard on all VAMP TAs. This allows the user to simply connect the FC/APC patch cable carrying the seed beam to the head. In this way, the seed beam is easily coupled into an internal fiber (b) that has been carefully pre-aligned to the input facet of the tapered amplifier diode and permanently fixed in place. This pre-aligned internal fiber ensures consistent and trouble-free alignment of the seed beam into the diode – every time. The seed and output power are monitored using two pick-off Si photodiodes (c). The amplifier output can either be fiber-coupled (d) or free-space. A 35 dB isolator at the output, not shown in the figure, is standard with every amplifier.

Fluctuations in the temperature of the tapered amplifier diode can adversely affect the VAMP TA performance, therefore temperature control is critical. Thermal isolation of the laser head is achieved by enclosing with thermally insulating foam (e) and the aluminum base of the tapered amplifier housing (f) acts as a dissipative heat sink. An on-board temperature sensor (g) is used to monitor the diode temperature and provides the input to the active temperature control closed-loop. Finally, a thermoelectric cooler affixed to the bottom of the diode block maintains a constant diode temperature.

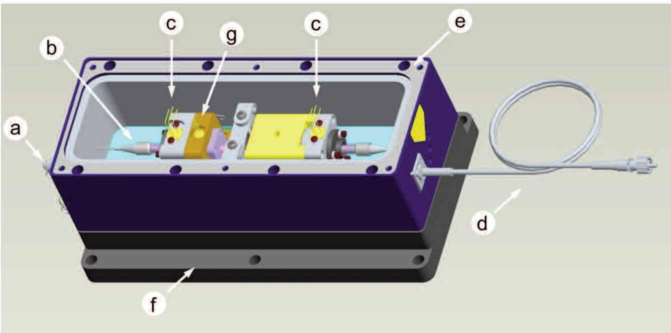

Figure 3. Glimpse inside a VAMP TA head.

The VAMP TA head is controlled using the TA-7600-LN Tapered Amplifier controller, which is shown in Figure 4. The system can be easily controlled through the new, easy-to-use multi-line display front panel interface. In addition, the controller is capable of automatically recognizing any 7600 Series VAMP TA head. This makes its use turnkey as the controller will maintain a constant diode temperature and limit the maximum current to the tapered diode according to information programmed into the circuit board in the head.

Remote control of the VAMP TA is possible via either the RS232 or USB port on the rear panel. Moreover, an intuitive Windows-based graphical user interface (GUI) application is included with each controller. The GUI permits the full functionality of the front panel (save for turning the key switch on/off) with the convenience of remote control. The next section illustrates the use of a VAMP TA system, laser head and controller, in amplifying the output of a New Focus seed laser.

New Focus™
A Newport Company

TA-7600 VAMP™ Tapered Amplifier

4. How To Use the New Focus VAMP™ TA System

Figure 5 shows a TLB-6718 Velocity laser head (a) and its TLB-6700-LN controller (b). This is being used to seed the VAMP TA system, head (c) and controller (d). As shown, with the Velocity laser set to λ=960 nm its fiber-coupled output is connected to the FC/APC input fiber connection of the VAMP TA head.

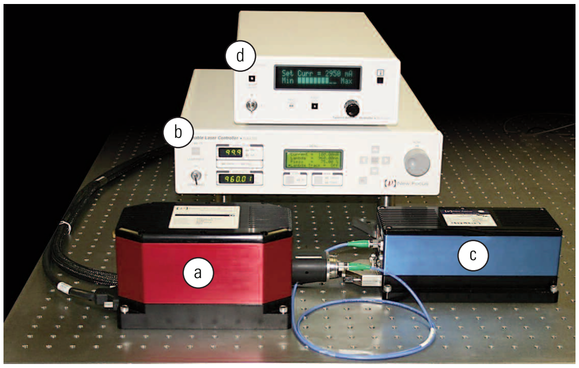

Figure 5. Seeding of a VAMP TA by a Velocity laser.

The VAMP TA system is turnkey! Turn the keyswitch on the front panel to the "I" position as shown in the Fig. 5. This will turn ON the system. On startup the display screen will cycle through a series of informative screens and stop at the main screen through which the user can control all VAMP TA settings. If P_{seed} < 10 mW, the *Input Power* LED will be lit red and you will not be able to turn the current ON to the tapered diode. This is a safety feature which prevents the user from degrading the lifetime of the tapered diode through "self-lasing". When $P_{seed} \geq$ 10 mW, sufficient seed power, the *Input Power* LED will be lit green allowing the current to the tapered diode to be turned ON.

The current to the tapered diode is turned on via the *Current On/Off* button. After the *Current On/Off* LED blinks six times, the control knob on the front panel can be turned to increase the diode current until the user reaches a desired diode current value or until an appropriate level of output power has been established. Unlike some other tapered amplifier systems, the New Focus VAMP™ TA system has been designed to prevent the user from unintentionally increasing the current to the tapered diode past its maximum operating current. After reaching an appropriate power level, the power lock feature of the VAMP TA system can be activated by pressing the *Power Lock* button. In this way, the output power can be highly stabilized with fluctuations exceeding no more than 1%.

Although the instructions above will be more than enough for most applications, detailed information on the operation of the VAMP TA can be obtained from the User's Manual.

5. Effect of Seed Laser Wavelength and Power On the Output of a VAMP TA System

Currently, each VAMP TA is built and tested using a New Focus Vortex™ Plus laser. However, any laser not exceeding the 100 mW maximum input power at the FC/APC connector can be used to seed a VAMP TA. However, not all seed lasers are created equal and the performance of a VAMP TA system will depend on a couple of seed laser parameters, including the *wavelength* and *power*.

To achieve optimal amplification the seed laser wavelength should match as closely as possible the center wavelength in the spectrum of the tapered amplifier diode. The example setup of Fig. 5 includes a VAMP TA. The spectrum for the tapered diode inside this VAMP TA is shown in Fig. 6 below and it shows, when being driven at a diode current of 3.3 A, a maximum in output intensity near 950-960 nm.

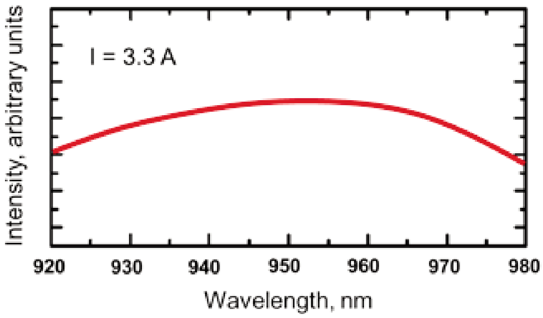

Figure 6. Output spectrum from 920-980 nm of the tapered diode inside the VAMP TA of Figure 5.

New Focus™ A Newport Company

TA-7600 VAMP™ Tapered Amplifier

To illustrate the effect of seed wavelength on VAMP™ TA performance, we took the setup in Fig. 5 and measured the output power from the VAMP TA as the seed wavelength was tuned from 945-975 nm. All else equal, we would expect that a graph of P_{out} vs. λ would qualitatively resemble the tapered diode spectrum in Fig. 6 with the greatest amplification occurring near the maximum in the spectrum. Figure 7 summarizes what was observed, after correcting for variations in the seed power with wavelength. Indeed, we see that the greatest amplification occurs in the vicinity of 950 nm near the maximum in the output spectrum of the tapered diode (950-960 nm). In addition, the shape of the amplification curve resembles the spectrum of the tapered diode above 945 nm. Therefore, although reasonable amplification can be achieved at other wavelengths, best results are obtained when the seed wavelength matches the wavelength corresponding to the maximum in the output spectrum of the tapered diode.

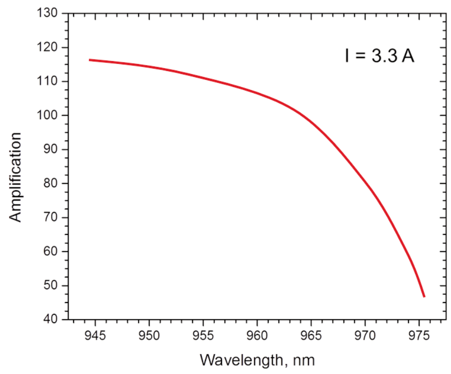

Figure 7. VAMP TA amplification as a function of seed wavelength.

To illustrate the effect of the seed power, the output power was measured now as a function of seed power, i.e. P_{out} vs. P_{seed}. The results are shown in Fig. 8. The plot shows an interesting trend of nearly linearly increasing output power with increasing seed power below approximately P_{seed} = 9 mW. Beyond this, there appears to be a plateau in the output power to give a less than linear dependence saturating at a value of approximately 1300 mW. Although the exact shape of this dependence will change with seed laser/VAMP TA pair, the overall trend in is clear: there is a regime in which the output power will nearly linearly depend on the seed power; however, after a certain value of seed power you see only diminishing gains in the output until P_{out} saturates.

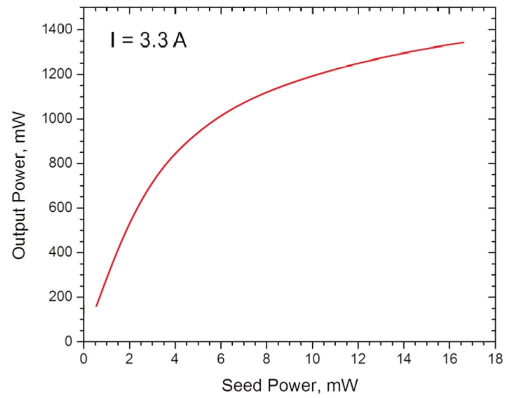

Figure 8. Seeding of VAMP TA by Velocity laser at 960 nm.

6. Summary

In applications requiring more power than can be provided by an ECDL, we have seen that the New Focus TA-7600 VAMP™ TA system is a robust solution. Its thoughtfully designed controller and safety features are user-oriented and it can be paired with New Focus lasers as well as "third party" lasers. We have also looked at how the output power can be highly sensitive to the seed laser wavelength and power by taking as an example a Velocity/VAMP TA pair. Although each seed laser/VAMP TA combination will lead to somewhat different output parameters, we have drawn some general conclusions and can use these to predict, roughly, the outcome of a given seed laser/VAMP TA pair. The New Focus TA-7600 VAMP™ TA system frees your mind from having to worry about power and keeps you focused on the science.

New Focus™
A Newport Company