How to run a *mini*TA

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1 Abbreviations

DBR laser	Distributed Bragg Reflector Laser
DFB laser	Distributed Feedback Laser
ECL	External Cavity Laser
ISO	Optical Isolator
LIV	Light Current Voltage Characteristic
MOPA	Master Oscillator Power Amplifier
PM	Polarization Maintaining
Seed laser	Lasers that are used for generating some seed light into an amplifier
TA	Tapered Amplifier

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2 Introduction

This application note is intended to demonstrate how to operate the *mini*TA amplifier modules to benefit from the stable performance and the high output power that is achieved in our R&D lab.

We will show how the *mini*TA is seeded and what special features, such as optical isolation and cooling, should be considered. It will be demonstrated by the example of a miniTA at 780 nm.. Some hands-on tips and tricks will be given for your reference, along with our on-site test results.

3 Application instruction

You just got a *mini*TA by TOPTICA EAGLEYARD. Now, the question is how to set up the amplifier so that it will perform as demonstrated in the specification.

The *mini*TA is an optical amplifier based on the design of semiconductor tapered amplifiers (TA). Thanks to our long-time know-how in the field of laser diode micro fabrication we were able to combine an effective fiber coupling on the input side with nearly diffraction limited beamshaping of the output emission in a compact 14-pin butterfly package.

Firstly, the laser package is hermetically sealed with thicker pins for higher ampacity, providing long-term stability. Secondly, the coupling into the ridge of the TA is done very efficiently via a single mode, polarization maintaining (PM) fiber, which enables us to achieve low saturation levels. Furthermore, the fiber coupling is resistant to environmental influences such as temperature fluctuations.

Compared to a simple setup on a C-Mount (see Fig. 1), we have eliminated the time-consuming free space coupling of the TA for the user. This eliminates the need for delicate handling of the TA exposed on the C-Mount as well as the complex coupling of the seed laser via one or more lenses. Additionally, thanks to the PM fiber, you no longer need to worry about the correct alignment of the input polarization.

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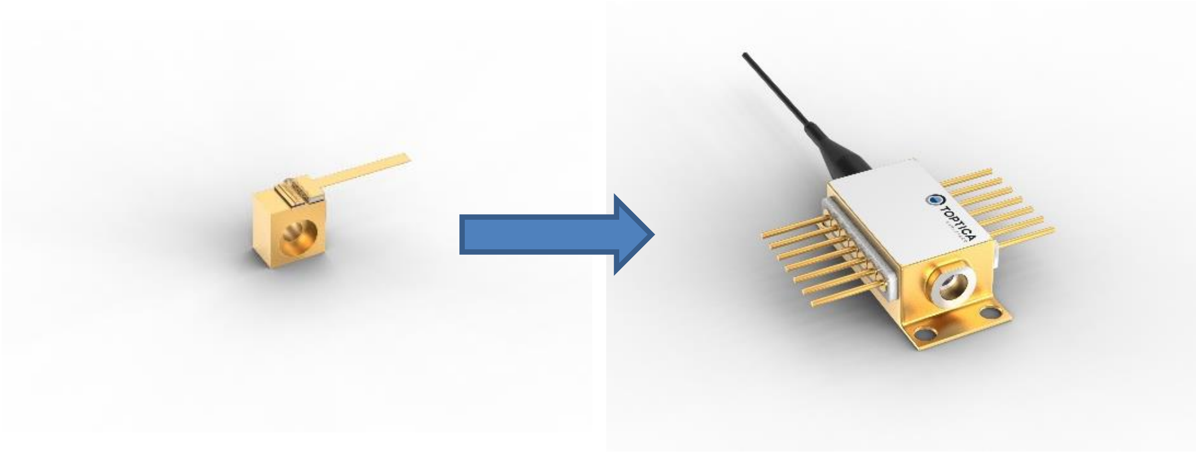

Figure 1 Miniaturization of tapered amplifier. Left: a commercial C-Mount. Right: a hermetic *mini*TA with fiber input and collimated output

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The input fiber is polarization maintaining (slow axis aligned to connector key; see Fig. 2) and assembled with a FC/APC connector (narrow key). This ensures direct compatibility with the fibers that are commonly available on the market. Please get in touch if you need other fibers or connectors.

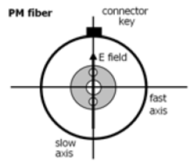
		Measurement Conditions / Comments
PM Fiber	900 / 125 / 5.5 µm, UV/Polyester-elastomer Coating (l = 1 +/-0.1 m)	
Connector	different variants available	

Figure 2 Input fiber and connector type

Due to the efficient fiber coupling on the input side of the *mini*TA, we only need a low saturation power of the seed laser.

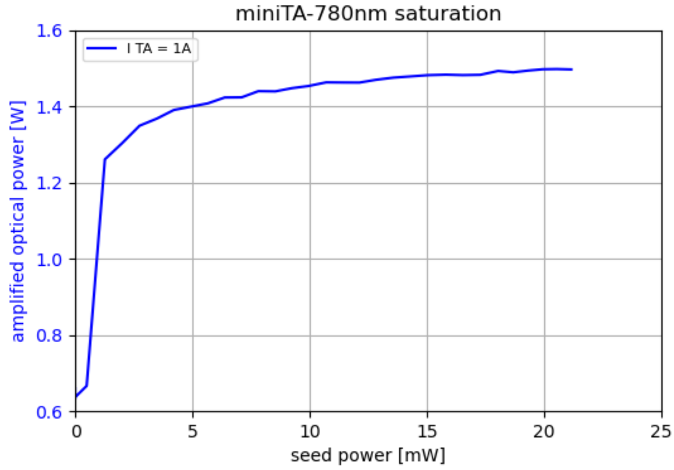


Figure 3 Saturation power of the *mini*TA seeded by a fiber coupled 780 nm DFB laser

Figure 3 shows the saturation power by using a 780 nm fiber coupled distributed feedback (DFB) seed laser in a standard 14-pin butterfly package and a *mini*TA 780 nm. It is evident that a saturation effect already occurs for an input power of 10 mW. This means that an input power of more than 20 mW is not necessary anymore.

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On the output side, we have saved the user a lot of work and have already collimated the amplified beam. The internal collimation is done via two cylindrical lenses, which also compensate for astigmatism. The collimation is performed at the operating point at nominal output power, providing the user with the best possible beam shaping for direct use of the collimated beam and for highly efficient optical fiber coupling. The output beam has an almost circular shape with a beam diameter of approx. 1 mm ($1/e^2$) and a low residual divergence of typically 2 mrad.

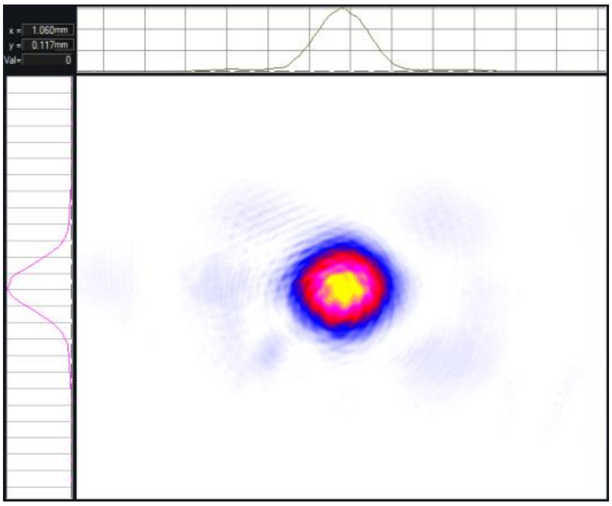

Figure 4 Beam profile of *mini*TA 780 nm at a distance of 0.6 m.

We optimized the beam profile with respect to the best possible suppression of side modes. Typically, the *mini*TA at 780 nm achieves a power in the central beam lobe of over 70%.

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4 Running in a MOPA setup

In most cases a tapered amplifier is used in a so-called MOPA setup. The spectral performance is given by the master oscillator (MO) or seed laser and amplified by the power amplifier (PA), in this case the *mini*TA. Most seed lasers are based either on DFB or DBR laser technologies or on ECL laser configuration (see also our *mini*ECL App-Note). These differ in terms of achievable linewidth, tuneability, stability or output power. However, all aforementioned laser designs are highly sensitive to back reflections or optical feedback in general. To prevent a disturbance of the single frequency operation, we need a sufficient optical isolation between the MO and the PA. The following measurement illustrates the influence of the isolator stage on the stability of the seed laser.

A simple test to determine the minimum isolation is the measurement of the speckle contrast. The speckle contrast is measured via a CCD image sensor and compared with the contrast value of the seed laser without subsequent amplifier). Depending on the required coherence length, an individual setup is required. A drop in the speckle contrast value is an indication of insufficient coherence after the *mini*TA and therefore insufficient isolation between the seed laser and the power amplifier.

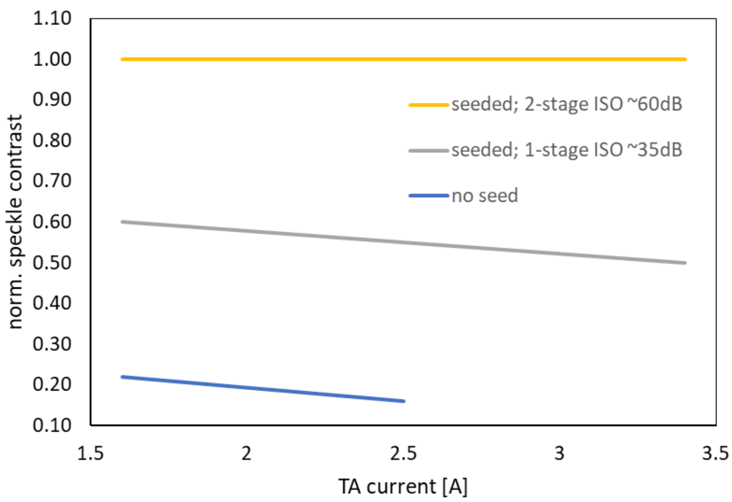

Figure 5 Speckle contrast vs. isolation level. Measurement without seed (blue), with seed and 35 dB isolation (gray) and 60 dB isolation (yellow)

In the example shown in Fig. 5, the normalized speckle contrast of 1.0 corresponds to a non-amplified coherence length of at least 2.5 m. For isolation levels of around 60 dB, the speckle contrast is independent of the *mini*TA current (yellow line in fig. 5). When using a single-stage isolator with about

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35 dB isolation, a significant drop up to 0.5 in the speckle contrast can be seen (grey line). In that case, stable operation can no longer be guaranteed.

The best isolation level between seed laser and amplifier depends strongly on the requirements of the application. Furthermore, the sensitivity of the seed laser to back reflections depends on the laser type. Derived from the measurements shown above, we recommend at least a double-stage isolator to ensure stable operation.

For easy use of a *mini*TA with popular spectroscopic wavelengths, we recommend the following fiber-coupled seed lasers in combination with an additional fiber isolator in the MOPA setup

Wavelength [nm]	**Seed-Laser (Master)**	**Isolator #1**	**Isolator #2**	**Overall Isolation**	***mini*TA Amplifier**
780.24 Rb D2	DFB-780-BFY12	build-in 35 dB	Thorlabs IO-J-780APC; 35dB	70 dB	TPA-780-BTU02
794.98 Rb D1	DFB-795-BFY12	build-in 30 dB	Thorlabs IO-J-795APC*; 35dB	65 dB	TPA-795-BTU02
852.35 Cs D2	DFB-852-BFY12	build-in 35 dB	Thorlabs IO-J-850APC*; 35 dB	70dB	TPA-850-BTU02

*Customized item. Please request availability from the supplier.

Another possibility is the combination with our *mini*ECL series. Here you simply use a commercial double-stage free-beam isolator (or several single-stage ones) with ≥ 60 dB and then couple into the input fiber of the *mini*TA as usual.

Wavelength [nm]	**Seed-Laser (Master)**	**Overall Isolation**	***mini*TA Amplifier**
770.11 K D1	ECL-770-BFW01	≥ 60 dB	TPA-765-BTU02
780.24 Rb D2	ECL-780-BFW01	≥ 60 dB	TPA-780-BTU02
852.35 Cs D2	ECL-852-BFW01	≥ 60 dB	TPA-850-BTU02

5 Notes on initial start-up

For an easy start-up of the new *mini*TA series, we provide a simple evaluation board (see our evalBoard APP-Note)

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We have optimized the connection of the thicker pins of the *mini*TA butterfly package as well as the thermal interface. You can identify the current version of the *mini*TA package by the "BTU" designation in the article name.

If you decide to use a custom laser mount, please refer to the interface drawing shown in Fig. 6. Due to the window frame of the package, we recommend to use screws with M 2.0 or alternatively UNC 2-56 threads. Please also note the maximum recommended tightening force for the screws of max. 0.2 Nm (see APP Note).

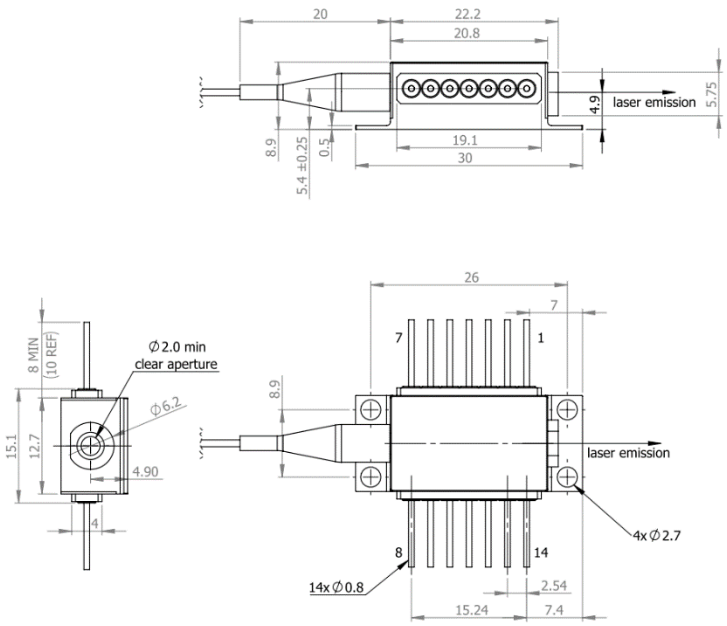

Figure 6 *mini*TA package drawing (new BTU-version)

Usually, commercially available butterfly laser diode mounts do not support the necessary ampacity of up to 5 A per pin. Furthermore, the pin diameter and especially the pin height often do not fit to our *mini*TA butterfly housing.

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1	Thermoelectric Cooler (+)	14	Thermoelectric Cooler (-)
2	Thermistor	13	not connected
3	not connected	12	not connected
4	not connected	11	Amplifier (Cathode)
5	Thermistor	10	Amplifier (Anode)
6	not connected	9	not connected
7	not connected	8	not connected

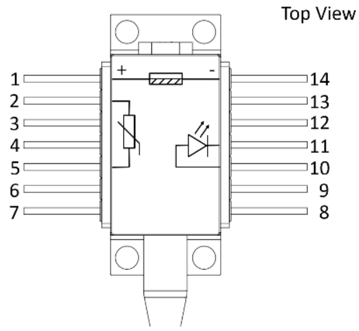

Figure 7 *mini*TA Package Pinning Table (new BTU-version)

In any case, please make sure that the *mini*TA is sufficiently cooled. The total heat loss at the package base plate is normally up to 10 W. Fig. 8 shows the heat dissipated by the module in relation to the TA current in seeded operation mode. Here, the heat loss is the total electrical power of the TA plus the power of the internal TEC minus the emitted optical power. For the measurements shown in Fig. 8 the *mini*TA module was mounted on an ideal water-cooled laser mount with a temperature difference between internal temperature of the TA and case temperature of 0 K.

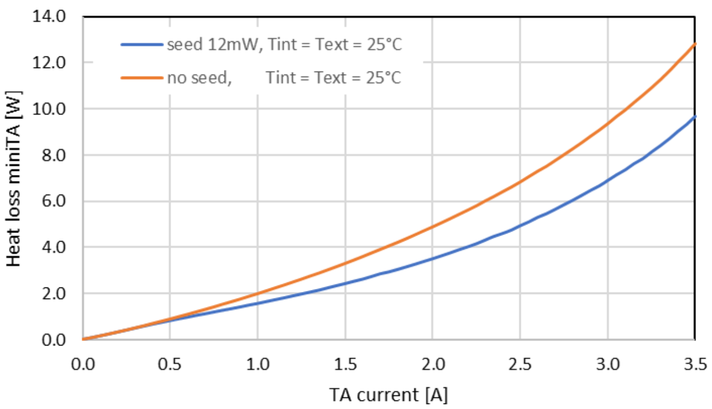

Figure 8 *mini*TA Package Pinning Table (new BTU-version)

Please ensure that the *mini*TA is always seeded during operation. We strongly advise not to operate the *mini*TA in unseeded mode with a TA current of more than 2 A.

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6 How to read the Test Protocol

The test protocol (see Fig. 9) shows the individual LIV characteristic in the MOPA setup with seed laser and isolator in the gain maximum with the minimum recommended seed power.

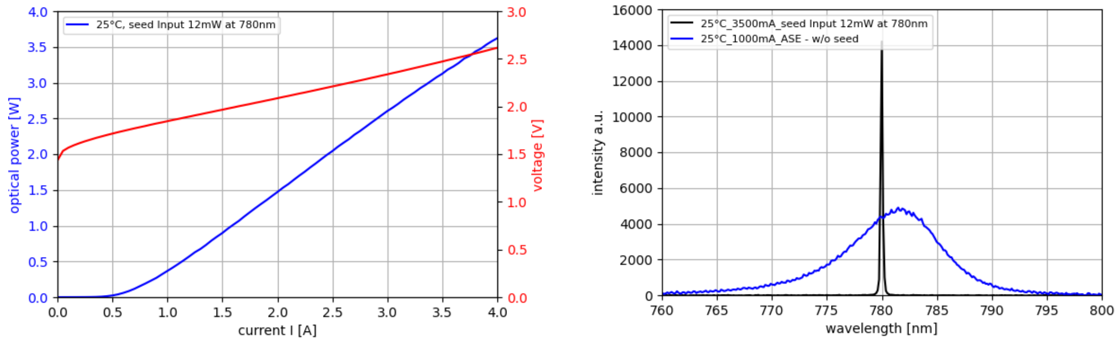

Figure 9 LIV (left) and spectrum (right) plots

The plot on the right shows the spectrum of the MOPA setup with the same seed laser at the nominal output power of 12 mW as well as the ASE spectrum without seed. This allows to estimate the gain bandwidth of the *mini*TA.

7 Appendix

If you have the older (non-hermetic) package version with the label BFU in front of you, please note the modified pin assignment (see Fig. 10 and Fig. 11). The pin assignment is rotated by 180° compared to the *mini*TA. Due to the low ampacity of the individual pins, the use of 2 pins each for anode and cathode is mandatory. Please also note the limited current range of 2.5 A for the internal TEC. Therefore, these modules can only be used in limited environmental conditions. Please also ensure a dry atmosphere, because BFU package is non-hermetic. Moisture entering the housing can lead to condensation and thus damage the TA.

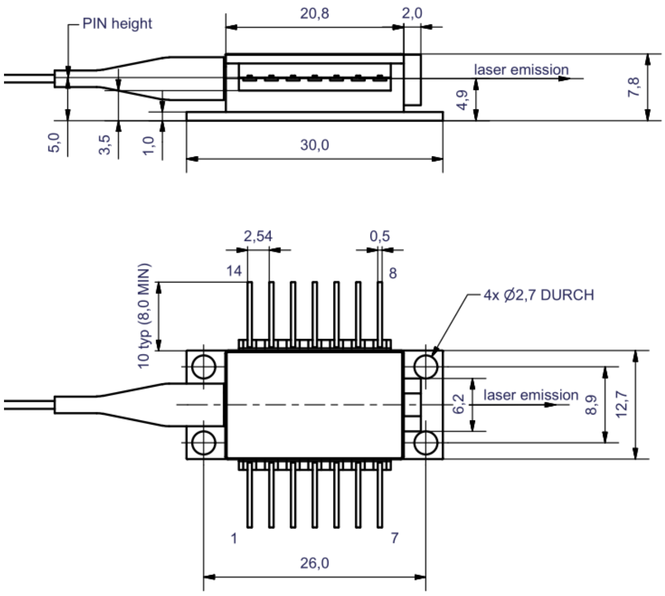

Figure 10 BFU package drawing (outdated non-hermetic sample version)

1	Thermoelectric Cooler (+)	14	Thermoelectric Cooler (-)
2	Thermistor	13	Case
3	not connected	12	Amplifier (Cathode)
4	not connected	11	Amplifier (Cathode)
5	Thermistor	10	Amplifier (Anode)
6	not connected	9	Amplifier (Anode)
7	not connected	8	not connected

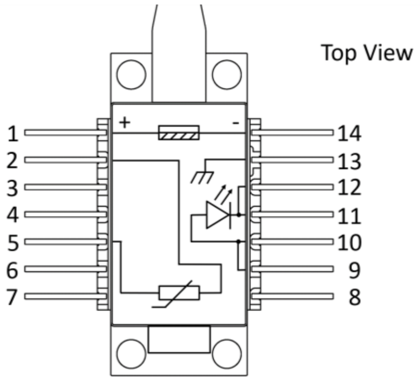

Figure 11 BFU pinning Table (outdated non-hermetic sample version)

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