Setting Up and Operating the *mini*ECL – A Compact External-Cavity-Diode Laser for Precision Applications

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1 Introduction

The *mini*ECL by TOPTICA EAGLEYARD is a compact external-cavity diode laser designed to deliver the performance of traditional ECDL setups in a hermetically sealed, alignment-free format. It combines a semiconductor gain chip with a volume Bragg grating (VBG) inside a hermetically sealed 14-pin butterfly package. This integration achieves ultra-narrow linewidths (on the order of 100 kHz), excellent side-mode suppression (typically 45–50 dB), and exceptional long-term stability, all in a compact form factor.

The *mini*ECL is available across a broad wavelength range (650–1100 nm), with standard models targeting key atomic and sensing lines including 671 nm (Li), 770 nm (K), 780 nm and 795 nm (Rb), 852 nm and 895 nm (Cs). Output power typically ranges from 40 to 100 mW depending on the wavelength and model variant.

This note will guide you through the process of setting up and tuning a *mini*ECL module, focusing especially on the 780 nm variant suitable for rubidium D2 spectroscopy, while covering principles applicable across the entire product family.

2 Key Features of the *mini*ECL

- **Ultra-Narrow Linewidth:** ~100 kHz, enabled by external-cavity feedback from the grating.
- **Hermetically Sealed Package:** No moving parts; ensures long-term reliability and environmental stability.
- **Mode-Hop Free Tuning:** Around ±10 pm (20 pm total) near the design wavelength, sufficient for atomic transition alignment.
- **Integrated Thermal Management:** Built-in thermoelectric cooler (TEC) and thermistor for stable operation and temperature-based wavelength control.
- **Integrated beam shaping:** Beam collimation for circular shaped beam profile
- **Fiber coupling and optical isolation:** Available with integrated optical isolation and polarization maintaining single mode fiber output
- **OEM-Ready:** 14-pin butterfly package, easily integrated into existing systems.

3 Getting Started with Your *mini*ECL

Upon receiving your *mini*ECL module, locate the included Test Protocol**.** This is a crucial document containing the individual characterization data for your specific unit. Before applying power:

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- **Review the Test Protocol:** Pay special attention to the working point (typical operating current and temperature) and the electrical pin configuration.
- **Pin Assignment and Circuitry:** At the bottom of the test protocol, you'll find the detailed pinout and wiring diagram. Be sure to connect the laser module correctly and stay within the specified limits to avoid permanent damage. Miswiring or exceeding the recommended operational specification can cause immediate failure.

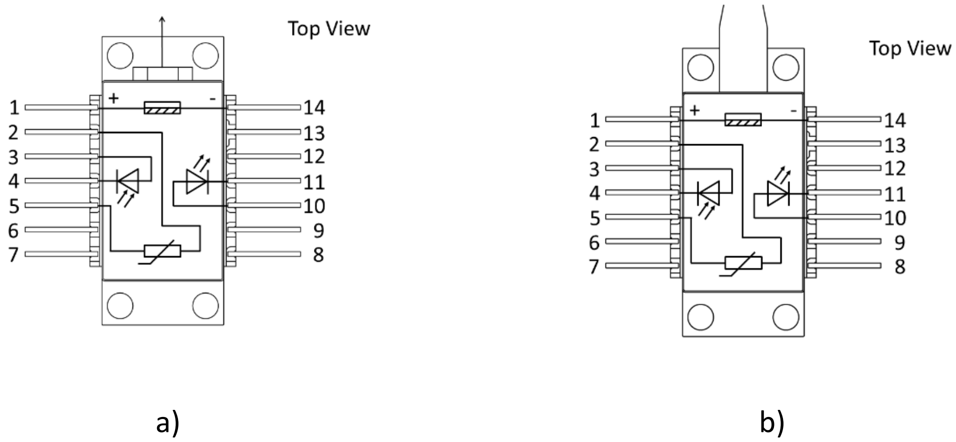

Figure 1: Pin assignment for *mini***ECL** with a) free space output and b) fiber coupling

Next, connect the module to a laser diode controller with appropriate current and TEC control. Power on the TEC first and set it to the recommended starting temperature—usually between 5 °C and 40 °C. Once the temperature is stabilized, slowly ramp up the diode current to the value specified in the protocol's working point.

4 Interpreting the Test Protocol

The top-left section of the test protocol typically includes a **P-I curve** (output power vs. current) and a monitor photodiode signal. These curves serve as a reference:

Specific Data of the Laser Diode (25°C):	
I at 80 mW [mA]	124
U at 80 mW [V]	1.9
λ center at 80 mW [nm]	780.1
Threshold Current [mA]	36
Slope [W/A]	0.9

P-U-I Characteristics

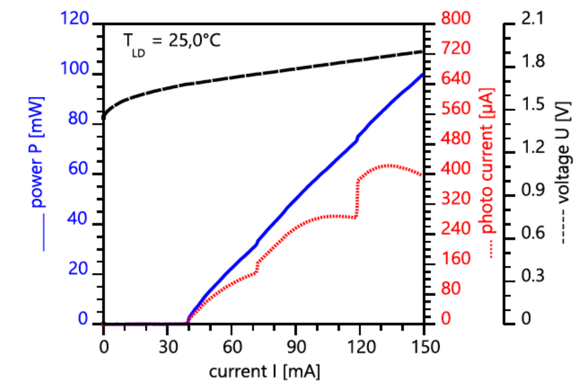

Figure 2: PUI characteristics at 25°C

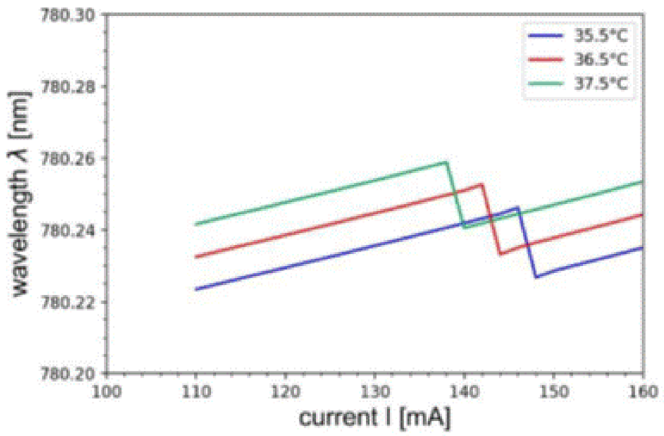

Figure 3: Working point/ spectral map of ***mini*ECL** from test document

- Set your drive current to the specified working point.
- Observe the output power and monitor diode signal.
- Ensure these values align reasonably with those in the test protocol.

This step confirms that the laser is undamaged and performing within specification. Deviations may indicate connection issues, optical misalignment (in free-space models), or thermal instability.

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5 Understanding Mode Hops

When tuning an external-cavity diode laser, it's common to encounter **mode hops,** which are sudden shifts in lasing wavelength. These manifest as discontinuities in the output power or photodiode signal and occur when the cavity resonance shifts out of alignment with the gain spectrum.

In the *mini*ECL, the short cavity length limits the number of supported longitudinal modes, reducing the frequency of mode hops. However, they still exist and must be managed carefully, especially when targeting specific wavelengths like 780.24 nm (Rb D2 line).

Typical signs of mode hops include:

- Sudden steps in the P-I curve.
- Jumps in the photodiode signal.
- Abrupt wavelength shifts when scanning current or temperature.

6 Tuning the *mini*ECL

To achieve mode-hop-free operation at your desired wavelength, you will need to tune both **temperature** (coarse) and **current** (fine).

6.1 Temperature Tuning

The *mini*ECL's emission wavelength shifts by approximately ~8 pm/K. This allows you to tune over a range of 0.2 nm within the safe operating temperature window of **5–45 °C**.

Procedure:

- Start from the base temperature provided in the test protocol.
- Adjust the TEC setpoint to bring the wavelength close to the target (e.g., 780.24 nm).
- Monitor the output using a wavemeter or spectroscopy signal such as a gas cell.

6.2 Current Tuning

Drive current affects the laser wavelength with a typical rate of **~1 pm/mA**. Once near the target, make small adjustments in current (±1–5 mA) to fine-tune the emission.

The goal is to find a stable region, where the wavelength remains stable despite small variations. This is typically at the center of a stable mode.

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6.3 Locating the Optimal Working Point

- Use the **wavelength-current-temperature map** included in the test protocol.
- Locate a region where the desired wavelength lies comfortably within a plateau, not near a mode jump.
- Set the temperature to place the target wavelength in the middle of this region, then adjust current accordingly.
- Once locked in, verify the emission with high-resolution wavelength measurement or optical beat note analysis.

7 Stabilization, Monitoring and Locking

Once your target operating point is found:

- Keep the TEC and current settings fixed.
- Use the built-in monitor photodiode to track output stability.
- Confirm long-term performance by checking for any drift or hop during extended operation.
- Further stabilization or locking is possible by modulating the injection current directly.

The hermetically sealed package and absence of moving parts ensure that, once tuned, the *mini*ECL provides **long-term spectral stability** with minimal user intervention.

8 Plug-and-Play Solution: Power up with *mini*TA

The fiber coupled *mini*ECLs provide plug- and -play solutions and are optimized for miniaturization, offering increased stability, reliability, and scalability—ideal for transitioning advanced photonics technologies from R&D into real-world, industrial applications.

Our *mini*TAs complements the *mini*ECL in a fully fiber-MOPA configuration, providing a compact, reliable alternative to high-maintenance and sensitive macroscopic laser setups.

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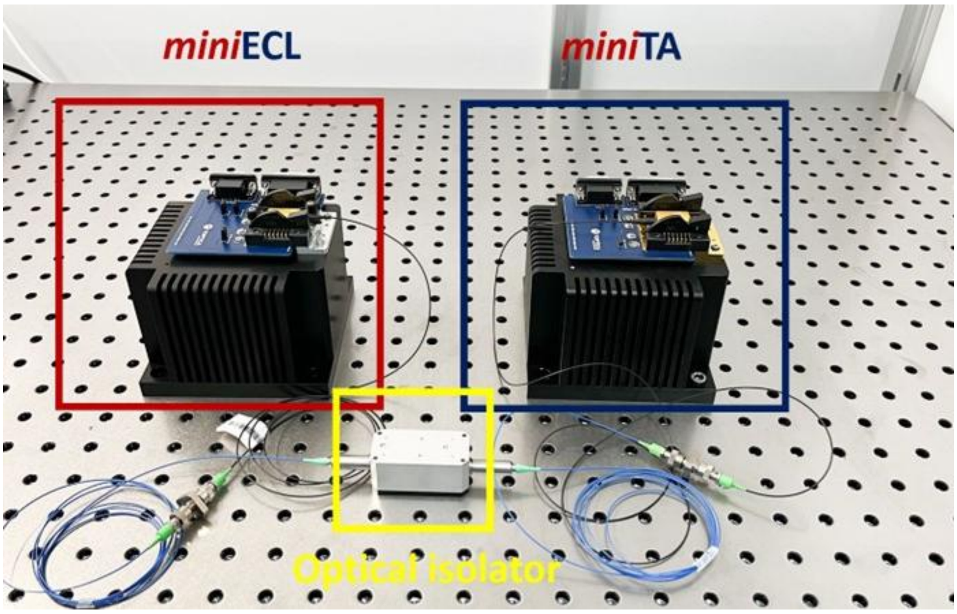

Figure 4: Full fiber based MOPA-setup with fiber coupled ***mini*ECL** and ***mini*TA**

(including fiber coupled isolator)

As a tapered amplifier, the ***mini*TA** has a fiber-coupled input and collimated output beam and is available in an optimized butterfly package with 14 thicker pins. This hermetically sealed housing is particularly advantageous in industrial applications, as the thicker pins guarantee an ideal supply of power. Furthermore, the forming of the beam, as well as thermal management, are also integrated.

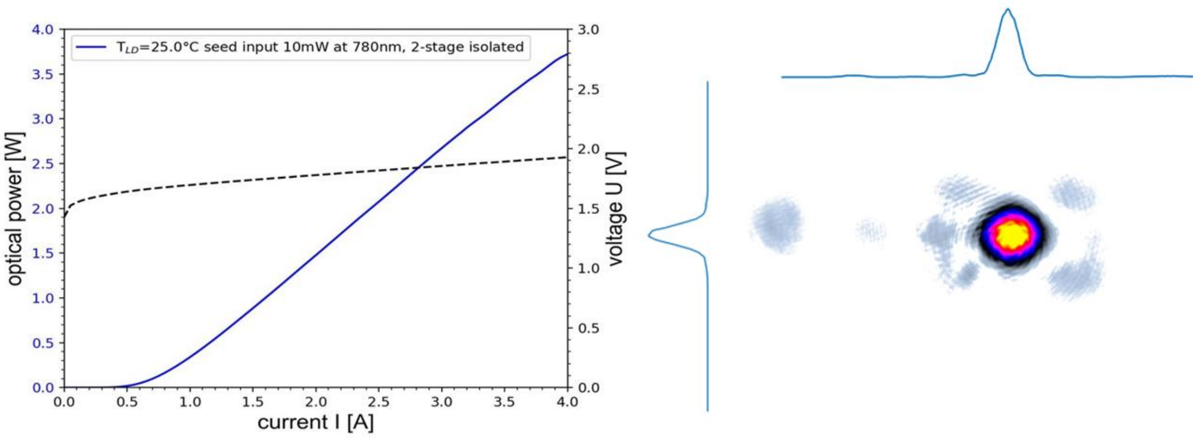

Figure 5: Resulting output power and beam profile for ***mini*TA** at 780 nm

9 Application Notes Across the *mini*ECL Family

While this guide emphasizes the 780 nm variant, all *mini*ECL models share the same architectural and tuning principles. Here are a few wavelength-specific notes:

- **670 nm (Li):** Output power ~40 mW, used in lithium spectroscopy.
- **770 nm (K):** Popular for potassium D-line studies, 80 mW nominal output.
- **795 nm (Rb D1):** High output power (100 mW) for targeting Rb D1 line
- **852/895 nm (Cs):** Suited for cesium transitions, typically 80 mW output.
- **Custom Wavelengths (650–1100 nm):** Available on request, with tuning and stability parameters similar to standard models.

For each model, the test protocol provides temperature and current maps tailored to the wavelength, enabling precise alignment to specific atomic or sensing lines.

10 Summary and Best Practices

To fully leverage the *mini*ECL's performance:

- **Always review the Test Protocol** before powering the device.
- **Use temperature for coarse tuning** (~0.01 nm/K), and **current for fine tuning** (~1 pm/mA).
- **Avoid mode hops** by selecting operating points in the center of stable plateaus.
- **Verify laser performance** with P-I curves, monitor diode readings, and wavelength measurements.
- **Stabilize temperature and current** during operation for best long-term performance.
- As every other **single frequency laser,** the *mini*ECL is sensitive to back reflections. Ensure sufficient optical isolation to protect the laser from external induced instabilities.

The *mini*ECL delivers exceptional performance in an industrial-grade format, enabling high-resolution spectroscopy, quantum sensing, metrology, and OEM integration with minimal complexity.

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11 Accessories

To make it easy to get started with our 14-pin Butterfly-based products, such as the *mini*ECL, we provide a simple evaluation board. No soldering is required for straightforward plug-and-play operation. Three versions of the evaluation board are available, each compatible with the pinouts and connectors of different vendors. Below is an overview of the evaluation boards, the compatible Butterfly-based products, and the pinouts:

evalBoard Product Version	9001 D-Sub connector Arroyo / ILX pinout	9002 D-Sub connector Thorlabs pinout	9003 Screw terminal	Note
*mini*ECL	✓	✓	✓	Max 5 A
*µ*MOPA			✓	Max 10 A, 2 sections
*mini*ECL / DFB	✓	✓	✓	Use supplied adapter