NIPM-I SERIES DETECTION MODULE USER GUIDE

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PRINCIPLE OF OPEARATION

The NIPM-I series of balanced/autobalanced IR detection modules is designed for differential optical signal detection. The modules can operate in both Balanced and Auto-Balanced Modes.

BALANCED MODE OPERATION

A block diagram of the electronic circuit is shown in FIGURE 1. The balanced/autobalanced detection module uses two individual IR detectors, manufactured by VIGO Photonics. The detectors (Signal and Reference) are precisely matched to ensure an exceptionally high Common Mode Rejection Ratio (CMRR). TE-cooled detector structures exhibit dark currents (on the order of tens of μA). To eliminate this current, manual compensation subcircuits are implemented.

The detectors are connected to two identical amplifier channels (Signal and Reference). Each channel consists of a transimpedance amplifier followed by a fixed voltage amplifier. Each channel (signal and reference) is connected - via a buffer – to and individual output. This configuration allows the balanced/autobalanced detection module to be used as a standard single-ended amplifier, which is especially useful for canceling dark current offsets. The exact value of the resultant transimpedance is provided in the Final Test Report, attached to each device. The signal channel output has inverted polarity: applying a laser signal to the detector structure will result in a negative voltage reading on the signal channel output.

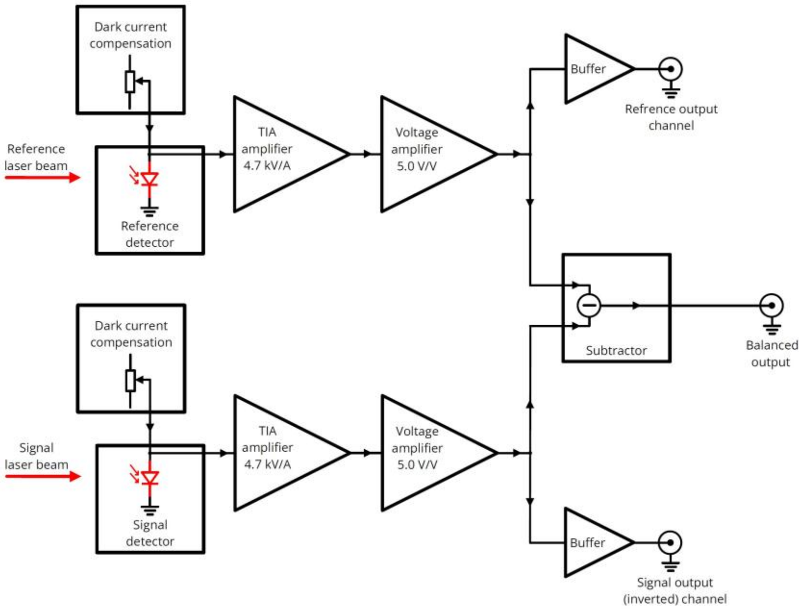

FIGURE 1. Block diagram of the detection module electronic circuit (Balanced Mode)

The Signal (SIG) and Reference (REF) channels are combined in the subtractor block. Any power difference in the optical signals (Differential Mode signal) will appear at the Balanced Output connector, while any unwanted Common Mode signal (especially excess laser noise) will be attenuated.

To achieve high attenuation of Common Mode variations in the optical signal (i.e., high Common Mode Rejection Ratio, or CMRR), the optical power received in the Signal and Reference beams should be as equal as possible (with an S/R ratio of 1:1). VIGO has performed both electrical and preliminary optical tests of the CMRR. By carefully adjusting the split ratio of the optical signals, it was possible to achieve more than 45 dB of CMRR over a wide frequency range. A measurement of the CMRR is shown in FIGURE 2.

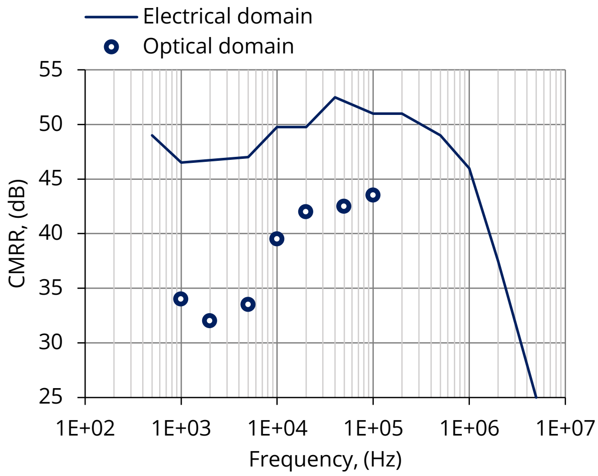

FIGURE 2. CMRR vs frequency (Balanced Mode, split ratio equals 1)

AUTO-BALANCED MODE OPERATION

Auto-Balanced Mode provides greater tolerance for imbalance between the signal and rference beams. The auto-balancing mechanism is implemented by introducing a negative feedback loop. As shown in FIGURE 3, the fixed Voltage Amplifier is replaced by a Variable voltage amplifier. An additional Integrator drives the Variable voltage amplifier to keep the low-frequency output signal components at ground potential.

If one of the optical signals (Reference or Signal channel) has lower power (e.g., attenuated by the sample under test), the low-frequency feedback loop adjusts the gain of the Variable voltage amplifier accordingly. The Signal channel is amplified or attenuated as needed, while any Common Mode signals (arising from laser excess noise) are greatly reduced, allowing accurate detection of the Differential Mode signals.

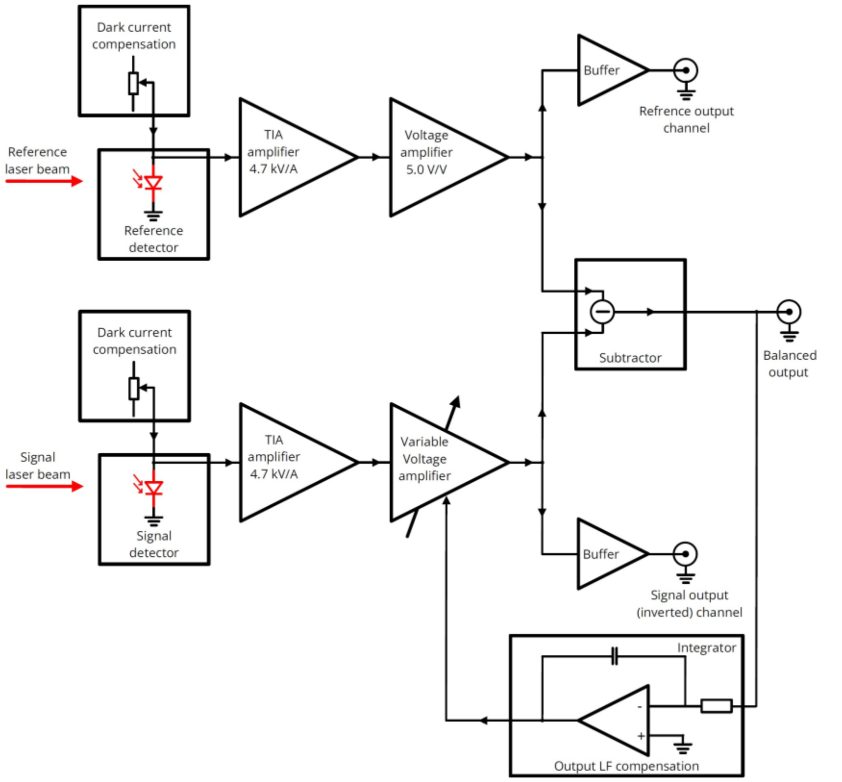

FIGURE 3. Block diagram of the detection module electronic circuit (Balanced Mode)

Electrical measurements of the CMRR versus split ratio (and frequency) are shown in FIGURE 4 and FIGURE 5. As shown, the best performance is achieved when the split ratio is approximately S/R = 1.

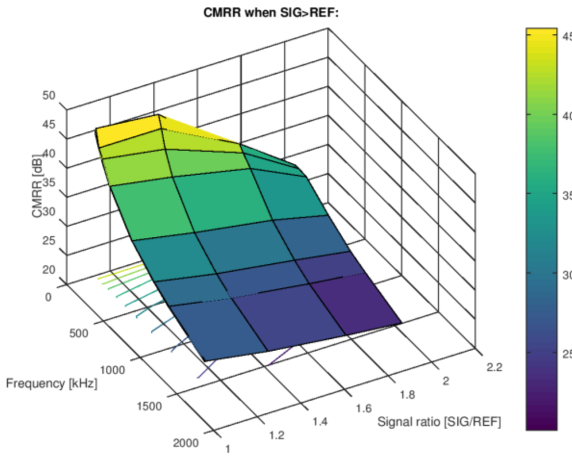

FIGURE 4. CMRR vs frequency vs split ratio
(signal optical power > reference optical power)

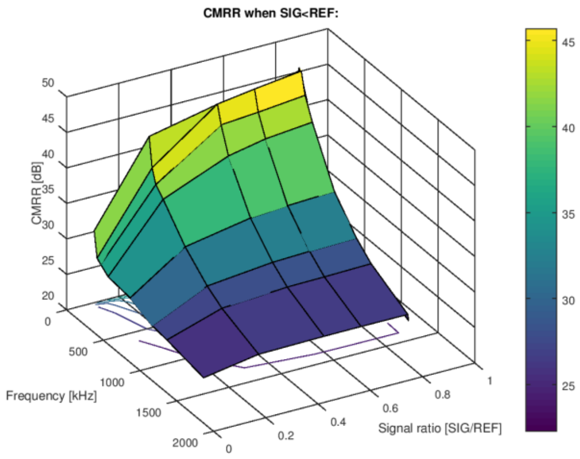

FIGURE 5. CMRR vs frequency vs split ratio
(signal optical power < reference optical power)

The auto-balancing compensation loop has a low cut-off frequency. This means that Differential Mode signal components below a certain frequency will be attenuated (in this design, the lower frequency limit is set to a few kHz). The Differential Mode Rejection Ratio (DMRR) versus frequency is shown in FIGURE 6.

In Auto-Balance Mode, it is essential to eliminate any dark current offsets. Any low-frequency (especially DC) parasitic signals will degrade the detection module performance by reducing the CMRR.

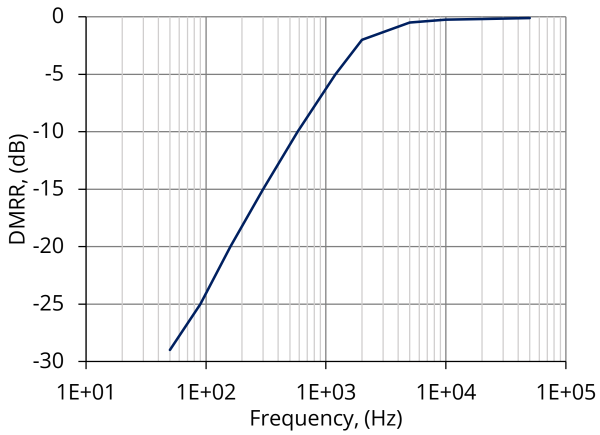

FIGURE 6. DMRR vs frequency (split ratio equals 1)

SYSTEM SETUP

The NIPM-I series detection module is supplied with all necessary accessories, as shown in FIGURE 7:

- 1 pc of AC Power cord (3.0 m)
- 3 pcs of SMA-BNC cables (1.0 m)
- 1 pc of AC/DC desktop power supply 9V/2A

FIGURE 7. NIPM-I series detection module with accessories (base mounting system and mounting post are not included).

GENERAL OVERVIEW

The detector side of the NIPM-I series detection module is shown in FIGURE 8. The detector structures are spaced 50 mm apart.

Threaded M3 mounting holes are provided for attaching optical accessories (see FIGURE 9).

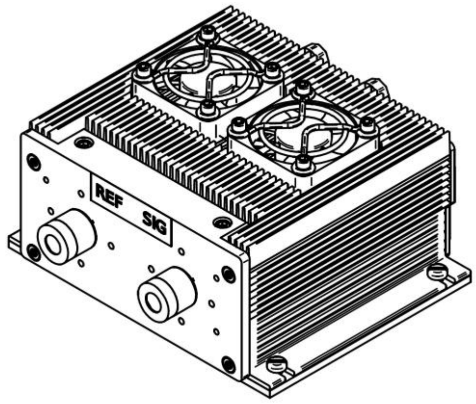

FIGURE 8. Detectors side of the NIPM-I series detection module

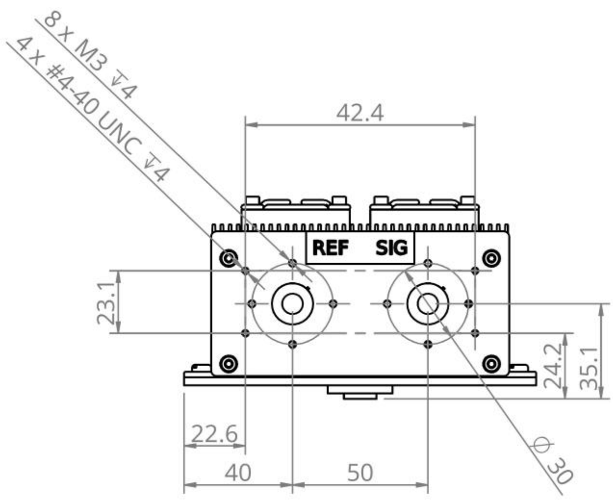

FIGURE 9. Mechanical layout of mounting holes for optical accessories (unit: mm)

CONTROL PANEL

The connectors and adjustment knobs are located on the panel, as shown in FIGURE 10. The functions of the controls are described in Section STARTING MEASUREMENTS.

FIGURE 10. Connector and control panel of the NIPM-I series detection module

DETECTION MODULE HEAT DISSIPATION

TE-cooled IR detectors require efficient heat dissipation. To achieve optimal performance of the detection module, it is essential to ensure unobstructed airflow through the device (see FIGURE 11). Mounting the detection module on an M6 post approximately 10 cm above the optical table is sufficient.

FIGURE 11. Airflow path through the NIPM-I series detection module

STARTING MEASUREMENTS

CABLE CONNECTION

A 9V/2A desktop power supply is used to power the detection module.

Three SMA-BNC cables are used to connect the detection module to an oscilloscope. Please note that the oscilloscope's input impedance should be set to 1 MΩ. It is recommended to observe all three channels: Signal, Reference, and Balance/Auto-Balance simultaneously.

POWERING UP

Switch on the power supply (see FIGURE 10). The PWR and OK LEDs on the panel should illuminate, indicating that the power supply is active (yellow) and the cooling process has started (green). The two fans will also start running. Within 1-2 minutes, the detectors should reach operational temperature, and the green OK LED should change to blue. A fully stable operating state is typically reached after approximately 4-5 minutes.

BALANCED MODE MEASUREMENTS

Move the toggle switch to the Balance position (pointing upwards; see FIGURE 10). Once the detectors have cooled and stabilized, measurements can begin.

The first step is to cancel the signal caused by the detector's dark current. To do this, turn off any external IR sources (e.g., laser, LED, or blackbody) and observe the output signals on the oscilloscope. You may see traces similar to those shown in FIGURE 12.

To eliminate the Reference channel offset unlock the potentiometer knob (see FIGURE 13). Adjust the voltage until it is as close to zero as possible (use the oscilloscope's averaging function). Lock the knob in place. Repeat the same procedure for the Signal channel. A compensated Balanced Detector signal is shown in FIGURE 14. At this stage, the device is fully operational, and you may turn on the external IR source. Low-noise differential optical signal detection is now possible.

For optimal performance, the compensation should remain undisturbed. Any unwanted external radiation (e.g., heat from the operator's hands or measurement equipment) can degrade the CMRR parameter. An example of this is shown in FIGURE 15, where the position of a previously compensated balanced detection module was changed, resulting in a loss of compensation.

FIGURE 12. Signals in Balanced Mode before compensation. Yellow – Reference output, green – Signal output, blue – Balanced output.

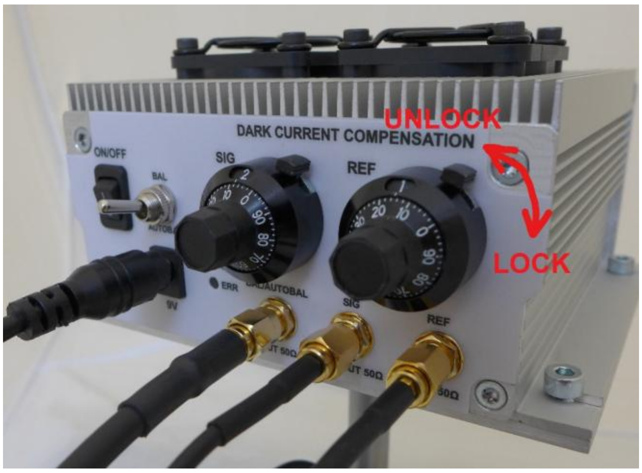

FIGURE 13. Adjusting the Reference channel compensation current by potentiometer knob.

FIGURE 14. Signals in Balanced Mode after compensation. Yellow – Reference output, green – Signal output, blue – Balanced output. Averaging enabled for clarity.

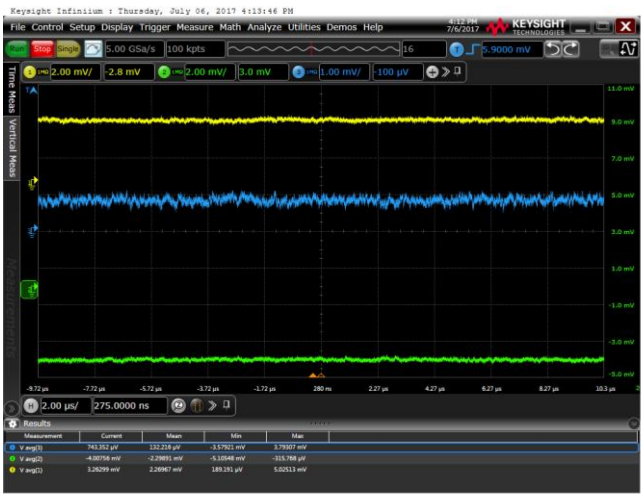

FIGURE 15. Signals in Balanced Mode after moving the compensated Balanced Detectors towards the oscilloscope. Yellow – Reference output, green – Signal output, blue – Balanced output. Averaging enabled for clarity.

AUTO-BALANCED MODE MEASUREMENTS

To perform measurements in Auto-Balanced Mode, it is first necessary to carry out dark current compensation, exactly as in Balanced Mode. Next, the external IR source may be switched on. Care must be taken to ensure that the Reference channel shows a positive reading and the Signal channel shows a negative reading (similar to FIGURE 15).

Set the toggle switch to the Auto-Balanced position (FIGURE 10). If the device has been properly compensated, the dalanced detection module is ready for operation.

In Auto-Balanced Mode, external IR radiation must be continuously applied to the detector structures. The ratio between the signal and reference radiation must satisfy the condition $0.2 < S/R < 2.0$, as shown in FIGURE 4 and FIGURE 5. Otherwise, the feedback loop will lock up, and differential detection will not be possible.