

ALIGNMENT OVERVIEW

Introduction

To acquire an accurate spectrum using the free-space port, it is critical to align the test source with the optical axis of the interferometer inside the Redstone spectrometer. In other words, it is important to optimize both the position at the OSA input as well as the angle of the input light. Good alignment results in an accurate wavelength reading and enables a good signal to noise ratio. This document provides a tutorial on free-space alignment for Thorlabs' Redstone OSA305 Optical Spectrum Analyzer (OSA). First, a general procedure is given, and then more detailed alignment schemes are discussed for three different types of sources.

Optical Setup

When using the free-space input, we recommend locking the Redstone OSA to the optical table using two or more clamping forks; see the "Using the Free-Space Input" chapter in the manual for additional details. To simplify the alignment process, two mirrors in kinematic mounts should be used between the test source and the OSA, where one mirror is close to the source and the other is close to the OSA's free-space port. Please see examples later in this document for mirror placement suggestions. If the beam height of your experimental setup is not consistent with the free-space input of the OSA, it is possible to modify the beam height by adjusting the tip and tilt of the two mirrors. Note that there is no need to keep the optical path parallel to the optical table until after the mirror closest to the OSA.

Initial Visual Alignment

Adjust the mirror closest to the test source to center the input beam on the OSA input. A viewing card, such as Thorlabs Item #s VRC2 or VRC6S, and/or an alignment plate, such as Thorlabs Item # CPA2, can be used to aid in the alignment. Then, open the "Free-Space Alignment" window from the Instrument menu in the OSA software, activate the alignment beam, and use the mirror closest to the OSA to point the alignment beam at the center of the input source.¹ Repeat, adjusting the two mirrors in turn until both conditions are fulfilled; the two beams then overlap over the entire beam path. To further optimize the alignment, the DC signal values of the detectors are shown whenever the alignment beam is active. Maximizing these values will most often lead to good interferometric signal values.

Final Alignment Using the OSA

Once the system is roughly aligned, deactivate the alignment beam in order to see a spectrum in the main software window. Change the resolution and sensitivity settings to Low, and start a continuous measurement. Use the "Free-Space Alignment" window to modify the gain levels. First, adjust the gain levels until the signal values lie between about 10% to 80%. Note that if the source is weak, the sensitivity may need to be increased, as this enables higher gain levels for some detectors. However, this will also slow down the measurements. If the source is strong, the attenuation filters can be activated through the "Free-Space Alignment" window. To optimize the alignment, there are several

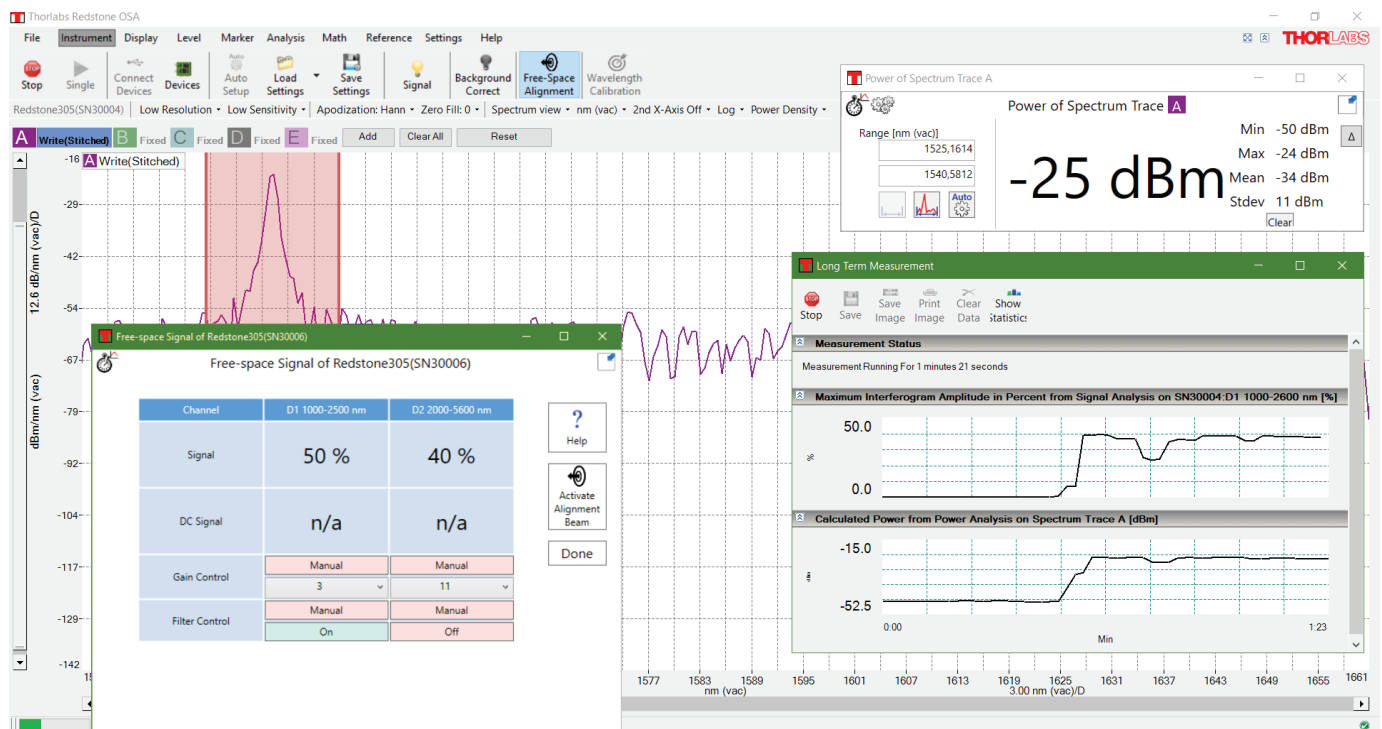


Figure 1: Software analysis tools that can be used during free-space alignment. Clockwise starting from the bottom left: the "Free-Space Alignment" window, Spectrum View in the main GUI, the Power tool, and a Long-Term measurement displaying the detected signal and power over time.

¹ If the input test source is sensitive to feedback from the alignment beam (~10 μW @ 635 nm), position a suitable dichroic mirror as close as possible to the test source.

software analysis tools that can be used; see Figure 1 for examples. In addition to the signal values in the “Free-Space Alignment” window, it is recommended to survey the detected optical power by using the Power tool and to observe either the interferogram or the spectrum.² A time series measurement of the signal and/or power can be started via the Long-Term functionality (see the “Long-Term Analysis” section in the manual) to get a reading of how these values change as the two mirrors are adjusted.

Once the desired software tools are selected and configured, repeat the alignment procedure described above but utilize the OSA readings instead of the viewing card to optimize the alignment. Remember to decrease the gain level or insert the attenuation filter if any detector is saturated.

Verifying Good Alignment

To verify that the alignment is good, the power detected by the OSA can be compared to a power meter reading taken at the OSA input. This is ideal for collimated beams small enough to not be affected by the OSA aperture.

For a monochromatic/narrowband source, good alignment is achieved when a flat interferogram envelope is observed for a high-resolution measurement; see Figure 2 for details.

Wavelength Error Estimation

When the signal cannot be optimized further, the wavelength error caused by any remaining misalignment can be calculated.³ The wavelength error, which is the path difference between the alignment beam and the source beam, can be estimated as

$$1 - \cos\left(\tan^{-1}(d/D)\right)$$

where d is the offset between the source exit point and the alignment beam, and D is the distance between the source and the detector. Note: D is the total distance, including the distance inside the OSA, between the free-space aperture and the detector; this value is 64 cm for the Redstone OSA305. It should be possible to have d better than 1 mm for $D = 1000$ mm, which yields an error of less than 5×10^{-7} . This is about 1 to 3 pm depending on the source wavelength range.

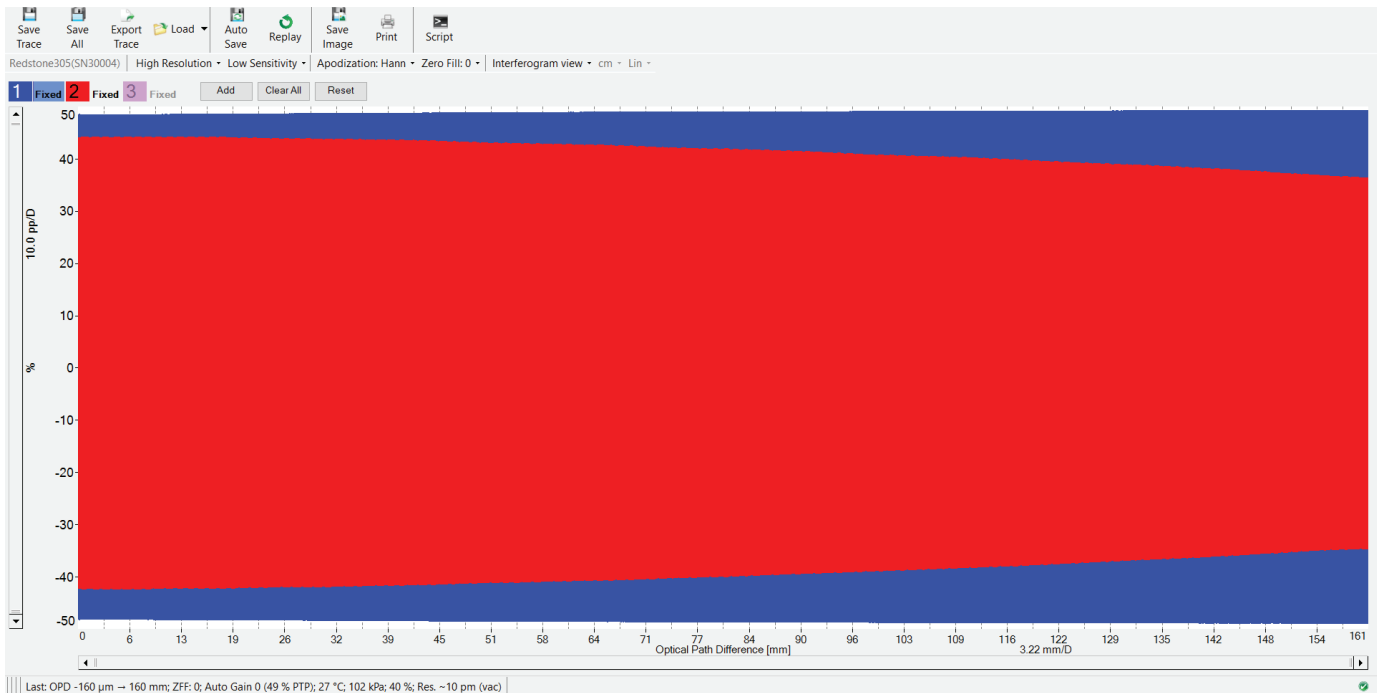


Figure 2: Interferograms corresponding to a (blue) well aligned and (red) misaligned laser source.

EXAMPLE 1: COLLIMATED SOURCE

Optical Setup

1. To simplify alignment, two mirrors in kinematic mounts should be used, where one is placed close to the input port of the OSA and the other near the optical source. One example of how the mirrors can be positioned for a collimated source is shown in Figure 3.

Initial Visual Alignment

2. Open the “Free-Space Alignment” window under the Instrument menu in the OSA software.

3. Turn on the alignment beam. Interferometric measurements are disabled while the alignment beam is activated, but the DC signal values of the detectors are available.
4. Adjust the mirror closest to the OSA such that the alignment beam falls onto the center of the optical source output.⁴
5. Adjust the mirror closest to the source such that the output beam is centered on the OSA input.⁴

² Spectrum View is often preferable if you have a narrowband source since the spectral peak is narrow while the interferogram ideally is flat. Typically, even a very weak frequency that is masked by noise in the interferogram shows up in the spectrum. Also, a small increase in the flat interferogram will affect a narrow peak much more. For a broadband source, a weak signal is typically easier to detect in the interferogram.

³ Note that an angular difference between the alignment beam, rather than the reference beam, and the test source beam will give rise to a small error in the measured wavelength.

⁴ A viewing card and/or an alignment plate can be used to aid in the alignment.

- Repeat steps 4 and 5 with smaller and smaller adjustments until no further improvements can be made. The beams now roughly overlap.

Start OSA Measurements

- Turn off the alignment beam. Interferograms and spectra are now enabled again.
- Set the OSA to Low Resolution and Low Sensitivity, which enables the fastest measurement rate.
- Start Continuous Sweep.
- Adjust the gain levels until the signal values lie within the 10% to 80% range. Note that if the source is weak, the sensitivity may need to be increased as this enables higher gain levels for some detectors. This, however, will also slow down the measurements. If the source is strong, the attenuation filters can be activated.

Final Alignment using the OSA

- Adjust the mirror closest to the source until no further improvements can be made on the detected signal values.⁵
- Repeat steps 3 - 4 and 7, 9, & 11 until no further improvements are found. If any of the detectors are saturated at any point in the process, decrease the gain level and/or insert the attenuation filter for that detector.

Alignment Verification (Optional)

- Compare the power detected by the OSA with a power meter reading taken at the OSA input.
- If the source is monochromatic/narrowband, the alignment can be verified by changing to High Resolution and observing a flat interferogram envelope, as shown in Figure 2.

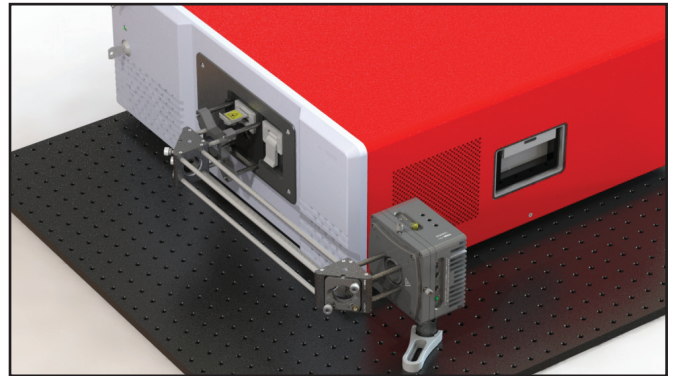


Figure 3: An example free-space setup for a collimated source, which includes a laser diode mounted in a Thorlabs LDM56 TE-Cooled Laser Diode Mount.

EXAMPLE 2: FIBER-COUPLED SOURCE

Sources with fiber-coupled output can either be connected to the fiber input port or coupled into the free-space port. The latter configuration provides the benefit of allowing filters or samples to be inserted into the light path prior to the OSA. In this case, the “Calibration Output” can provide additional assistance in the alignment process.

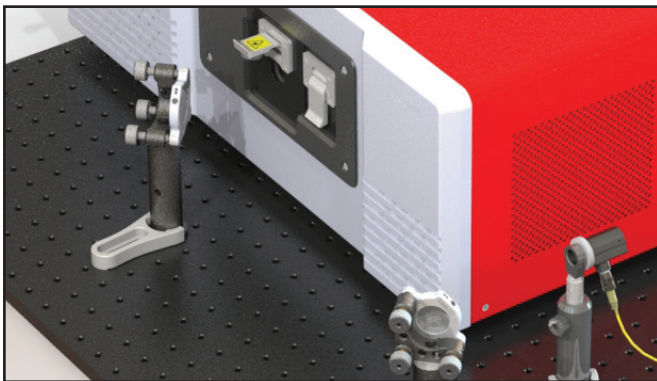


Figure 4: An example free-space setup for a fiber-coupled source.

Optical Setup

- To simplify alignment, two mirrors in kinematic mounts should be used, where one mirror is placed close to the input port of the OSA and the other near the optical source. One example of how the mirrors can be positioned for a fiber-coupled source is shown in Figure 4. Note that a reflective collimator should be used, since refractive optics are inherently dispersive and will disturb the wavelength composition of the input light.

Initial Visual Alignment

- Open the “Free-Space Alignment” window under the Instrument menu in the OSA software.
- Turn on the alignment beam. Interferometric measurements are disabled while the alignment beam is activated, but the DC signal values of the detectors are available.

- Adjust the mirror closest to the OSA such that the alignment beam falls on the center of the collimator.⁶ Alternatively, the fiber can be removed from the collimator and the alignment beam exiting the collimator input optimized.
- Connect a suitable fiber (for example, the included P5-SMF28E-FC-2) to the “Calibration Output” port and the collimator. With the alignment beam turned on, the “Calibration Output” emits both an infrared (IR) beam (the reference) and the red alignment beam, albeit with a lower intensity than from the free-space
- Adjust the mirror closest to the collimator such that the IR and red beams are centered on the OSA input.⁷
- Repeat steps 4 and 6 with smaller and smaller adjustments until no further improvements can be made. The beams now roughly overlap.

Start OSA Measurements

- Turn off the alignment beam to enable interferograms and spectra again. Reconnect the test source to the collimator.
- Set the OSA to Low Resolution and Low Sensitivity, which enables the fastest measurement rate.
- Start Continuous Sweep.
- Adjust the gain levels until the signal values lie within the 10% to 80% range. Note that if the source is weak, the sensitivity may need to be increased as this enables higher gain levels for some detectors. This, however, will also slow down the measurements. If the source is strong, the attenuation filters can be activated.

⁵ See suitable software analysis tools described earlier and in Figure 1.

⁶ A viewing card and/or an alignment plate can be used to aid in the alignment.

⁷ A semitransparent material, e.g., a piece of paper, can visualize the red beams from the OSA input and the collimator simultaneously.

Final Alignment using the OSA

- Adjust the mirror closest to the source until no further improvements can be made on the detected signal values.⁸
- Repeat steps 3 - 4 and 8, 10, & 12 until no further improvements are found. If any of the detectors are saturated at any point in the process, decrease the gain level and/or insert the attenuation filter for that detector.

EXAMPLE 3: DIVERGENT SOURCE

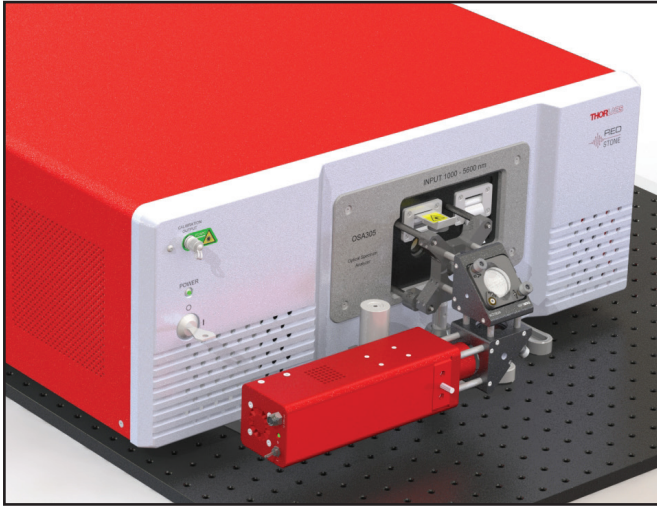


Figure 5: An example free-space setup suitable for a broadband divergent source, which includes the Thorlabs SLS203L Stabilized Free Space light source. The source is kept at a short distance from the OSA to minimize input losses.

Optical Setup

- For a divergent source, the angle of incidence is less important than for a collimated source. To avoid losing a significant amount of light due to the divergent beam, the source is positioned close to the OSA (see Figure 5). If the source is weak, one of the two alignment mirrors can be removed to minimize the distance between the source and OSA.

Initial Visual Alignment

- Open the “Free-space Alignment” window under the Instrument menu in the OSA software.
- Turn on the alignment beam. Interferometric measurements are disabled while the alignment beam is activated, but the DC signals of the detectors are available.
- Adjust the mirror closest to the OSA such that the alignment beam falls onto the center of the optical source output.⁹
- Adjust the mirror closest to the source such that the output beam is centered on the OSA input.⁹
- Repeat steps 4 and 5 with smaller and smaller adjustments until no further improvements can be made.

Alignment Verification (Optional)

- Compare the power detected by the OSA with a power meter reading taken at the OSA input.
- If the source is monochromatic/narrowband, the alignment can be verified by changing to High Resolution and observing a flat interferogram envelope, as shown in Figure 2.

Start OSA Measurements

- Turn off the alignment beam. Interferograms and spectra are now enabled again.
- Set the OSA to Low Resolution and Low Sensitivity, which enables the fastest measurement rate.
- Start Continuous Sweep.
- Adjust the gain levels until the signal values lie within the 10% to 80% range. Note that if the source is weak, the sensitivity may need to be increased, as this enables higher gain levels for some detectors. This, however, will also slow down the measurements. If the source is strong, the attenuation filters can be activated.

Final Alignment using the OSA

- Adjust the mirror closest to the source until no further improvements can be made on the detected signal values.⁸ If any of the detectors are saturated at any point in the process, decrease the gain level and/or insert the attenuation filter for that detector.

Alignment Verification (Optional)

- Due to the divergence of the light source, some portion of the light will not reach the internal detectors and a comparison between the power read by the OSA and the detector positioned outside the OSA cannot be relied upon in this case.
- If the source is monochromatic/narrowband, the alignment can be verified by changing to High resolution and observing a flat interferogram envelope, as shown in Figure 2.

⁸See suitable software analysis tools described earlier and in Figure 1.

⁹A viewing card and/or an alignment plate can be used to aid in the alignment.