Evaluation of Systems for Exchanging Lasers and Associated Optics on a Dispersive Raman Instrument

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Overview

Purpose: To evaluate methods for exchanging lasers on dispersive Raman instruments.

Methods: Evaluate and then design an instrument that has easy to exchange optical components.

Results: A Raman instrument that has components that can easily and reliably be exchanged by the user while maintaining alignment and calibration.

Introduction

Changing lasers on a dispersive Raman instrument normally takes one of two paths, either it is a process that involves potentially disassembling the instrument, or it is a fully automated process. This poster compares and contrasts designs for easily changing lasers on a dispersive Raman system. A related and important part of the process is changing the filters and gratings associated with changing to a different wavelength laser, or changing to a different resolution grating while maintaining the same excitation laser. For a truly effective system the affected optics also need to be easy to change. Some relevant issues that need to be addressed are signal reproducibility, optics alignment, and calibration. This poster will evaluate several design approaches for changing lasers with consideration focused on the efficiency of the change and the effect on results. Another critical aspect of the evaluation is how the design impacts the user. This is important because the degree of difficulty in changing the components determines how efficiently the system will serve as an analytical tool and the level of training that an operator will require.

Initial assessment showed that there were two primary modes of exchanging components on a dispersive Raman instrument, an automated approach and a completely manual approach. First we will discuss the initial two methods, and then demonstrate a new mechanism, that we call SmartLock technology, appears to combine many of the advantages of each of the previous approaches.

Background

As previously mentioned there were historically two primary approaches to exchanging optical components on a dispersive Raman instrument, the automated approach and the manual approach.

A fully automated instrument handles all the switching of components, with minimal input from the user. Ideally, choices are made in the software and instrument performs the switching of lasers, gratings, filters, and related optics. The advantage offered by this approach is that if it is fully automated, it can be extremely simple and very fast to operate. There are some potential drawbacks to this approach though. The most notable are that the instrument may be larger than desired to provide space for all of the potential components, the up front investment will certainly be higher, the additional automated components may require more frequent servicing, and finally upgrading the system to include more components after the initial installation is generally a more complicated venture. There are also some hybrid designs out there in which some components are automated and others are not. The benefit of the automation in these system is weakened and generally the same drawbacks still exist.

A completely manual instrument means that the user is responsible for changing and optimizing the alignment of all of the required components on their own. The benefits here are that the system will be less expensive, often it can be smaller, and there is often a great deal of flexibility. There are some drawbacks to this approach. First, is that it is likely that the user will have to open the instrument up to change components where they could be exposed to laser radiation and they could be exposed to high voltage from the electronics. Second, this approach requires a well trained user, confident in their skills. In terms of time, this approach takes significantly more time during normal usage, but a skilled user can change parts more quickly if replacement or repair is needed. An important aspect to be considered with this approach is alignment and calibration. By changing components manually the user creates a need to check and verify the alignment and calibration of the new components. Again this adds time to the process, as the user will need to take time to re-calibrate and re-align the new components before being able to perform any analyses.

Results

As can be inferred from the above, the two design approaches both have attractive benefits. The aim of the development effort described here was to devise a system in which key benefits of both approaches could be realized; the exchange needed to be fast, safe and easy to for anyone to perform, it had to maintain alignment and calibration, yield highly reproducible results, be easily upgradeable, and not overly burden the initial investment with expensive components that may not be useful with the initial configuration.

FIGURE 1. Changing the filter

FIGURE 2. Changing the grating

Those considerations were taken into account in the design of the DXR Raman instruments, both the Raman Microscope and SmartRaman systems.

Optical components were designed to be easy to remove and replace. As can be seen in Figures 1 and 2, changing a filter or grating is very straightforward and easy, plus there is no need to open up the instrument to access these components. To change a filter it merely needs to be pulled up and out of the instrument. A grating can be changed by opening the grating door, grasping the grating by its handle and pulling it out. Adding in a new filter or grating is just as easy, the user puts the grating into position and it locks into place using SmartLock. SmartLock consists of a designed base in the instrument and robust magnets to hold the components into place. Putting a grating or filter into place is very easy, as the component gets close the magnets pull the component into place and “lock” it there securely, the design of the base properly aligns the components so there is not a concern about a component being out of alignment when installed.

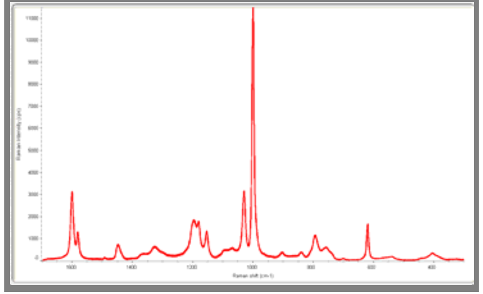
Figures 3 shows the laser and instrument while Figure 4 shows the installation of a laser onto the instrument. The lasers are put in place, then locked down by the handle on the laser sled, ensuring alignment, and laser safety.

All components are pre-aligned at the factory, so once they are installed, running an automated alignment and calibration procedure is all that is needed. Then the components can be exchanged as often as desired.

FIGURE 3. Laser and attachment to the instrument

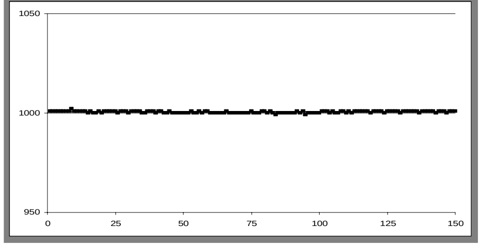
FIGURE 4. Changing the laser

FIGURE 5. Polystyrene spectra, 150 spectra collected, removing and replacing the 532 nm grating in between collection of each spectra.



Another important feature is that the instrument remembers the different components. This is achieved by using iButtons on the filters, grating, and lasers. Once a component is aligned and calibrated the instrument stores the information about the identity of the component and the proper settings for good alignment and calibration. Also the iButtons ensure that proper components are matched up, for example a 780 nm filter can’t be used with a 532 nm laser and grating, the software recognizes the discrepancy and tells the user. Another benefit of the iButtons is that they are also used to track laser usage, so it is very easy for the user to check the laser and how many hours it has been used, this information is stored on the iButton, so if the laser is swapped to another instrument the usage is not reset to zero hours. By storing the identity of the components validation and other processes that require strict control of information are made automatic by the computer, making the job of the user much easier, and making the process reliable.

FIGURE 6. Plot showing the recorded position of the 1001.4 cm^{-1} peak of polystyrene after each grating removal and replacement.



One of the design requirements was for reproducibility. The design of thee components, the design of the component bases in the instrument, the robustness of the magnets, and the overall robust optical design allow it to meet this requirement. To demonstrate this a system was set-up with 532 nm components and a sample of polystyrene was analyzed. Two exposures of 2 seconds each were collected, then the grating was completely removed, replaced, and another pair of exposures were collected. This was done 150 times in total. All 150 spectra are shown overlaid in Figure 5. By monitoring the location of the 1001.4 cm^{-1} peak of polystyrene we were able to follow the reproducibility. A plot of the peak position versus number of the exchange is shown in Figure 6. The standard deviation for the reproducibility, calculated using the location of the 1001.4 cm^{-1} peak was 0.518 cm^{-1}. This result shows that the design does give good reproducible results when exchanging optical components without the need to repeat the calibration each time.

Conclusions

In conclusion it can be seen that there is now a third option when it comes to options for exchanging lasers and associated optics on a dispersive Raman instrument. Before there were two options, at each end of the scale in terms of ease of operation, one fully automated, one fully manual. Now the third option fits nicely into the middle and offers many of the benefits of each approach. The components are easy to switch, safe to switch, can be done quickly, and do not burden the instruments with unneeded investment. And as has been shown, the system maintains very good reproducibility even after 150 exchanges of one of the critical optical components. Figures 7 and 8 show the DXR Raman instruments designed using these concepts, in particular the SmartLock technology with the iButtons.

FIGURE 7. The DXR Raman Microscope built using the SmartLock technology for easy to exchange optical components.

FIGURE 8. The DXR SmartRaman system built using the SmartLock technology for easy to exchange optical components.