Breakthrough: Filters now fluky to capture fine details in spectrometers!

Here comes a good news for the spectrometer community: Fluky, rather than careful and elaborately designed, filtering of light can boost spectrometer's resolution by 10-fold to the existing limit. Hence, now is the time to supplant the old-fashioned painstaking brick-wall filter design by fluky filter design. This shift in paradigm with its added profits have been recently unveiled by Professor Heung-No Lee at INFONET laboratory, GIST, South Korea, and his research team with the post-doctor J. Oliver and the doctoral student Woong-Bi Lee. Armed with the new design strategy, Prof. Lee's team was able to demonstrate a new portable spectrometer system which can deliver fine spectral details about objects, using cheaply made filters but employing a sophisticated signal processing algorithm. Their research finding, which will be published in February 2013 in a highly referred top journal in Optics, Optics Express, is expected to hit the resolution-demanding spectrometer industry.

Spectrometers are optical instruments that capture light, break it into its various colors (wavelengths) and display them in the form of spectrum similar to a rainbow. The spectrum reveals structure and composition of objects under study. Spectrometers are used to analyze proteins and light sources, to identify oil spills, to determine the mineral distribution on a planet's surface, to discover drugs, to inspect food quality, to name a few. In all these applications, resolution—the ability of the spectrometers to distinguish between details of the objects—is the key criterion that rates the spectrometer quality. Thus, spectrometer industries demand innovative methods that substantially improve the resolution.

A family of spectrometers that are built with an array of optical filters offers miniaturization, superior portability, and cost effectiveness. The fraction of light that an optical filter transmits at a specific wavelength is called transmittance. Thus, each filter is specified by its transmittance as a function of wavelength. The design of transmittance of each filter and the number of filters determine the resolution for this family of spectrometers. Improving resolution by increasing the number of filters is obvious but a costly option, not suitable for portable and low cost spectrometers. What Prof. Lee's team aimed at is to attack the problem at the heart of the filter array based spectrometers, and to improve resolution by employing a clever idea in the back processing algorithm they use to process the raw spectrum.

The crucial question Prof. Lee's team has asked is this: What shapes of transmittances are good for improving resolution? The team first discovered that a traditional, ideal, brick-wall like transmittances (see Figure) acquire information about an object only from a portion of the spectrum. The additional piece of spectral information outside the local spectral region is avoided by stringent filter design. In the past, with the lack of sophisticated back processing method, the additional information is considered as distortion. But when such a back processing can be easily done, it should be included. Thus, in a viewpoint completely different from the traditional one, the team considered the distortion as an additional means to extract useful information about the spectrum. With this new approach, the team has found that each filter should seek to acquire not the local information but the global spectral information. Each filter makes redundant but independent observation of the whole spectral information. As a group of filters, this way of making observation is much better off than the old fashioned brick-wall design approach. This new strategy for acquiring global information is done simply by making the transmittance function of each filter randomly shaped (see Figure).

By random filters, they mean two things. First, the transmittance of a filter at one wavelength is completely different and uncorrelated with that at the other wavelength. Second, the shape of each filter's transmittance is uncorrelated with the other filters in the set. Such a set of filters are fluky in their characteristics and quality. They can be designed and manufactured effortlessly. Filters whose transmittance function is random can be easily generated by using thin film optical filter technology, the research article has shown. Though fluky, they are much better off at providing fine details in the light they see, their research has found.

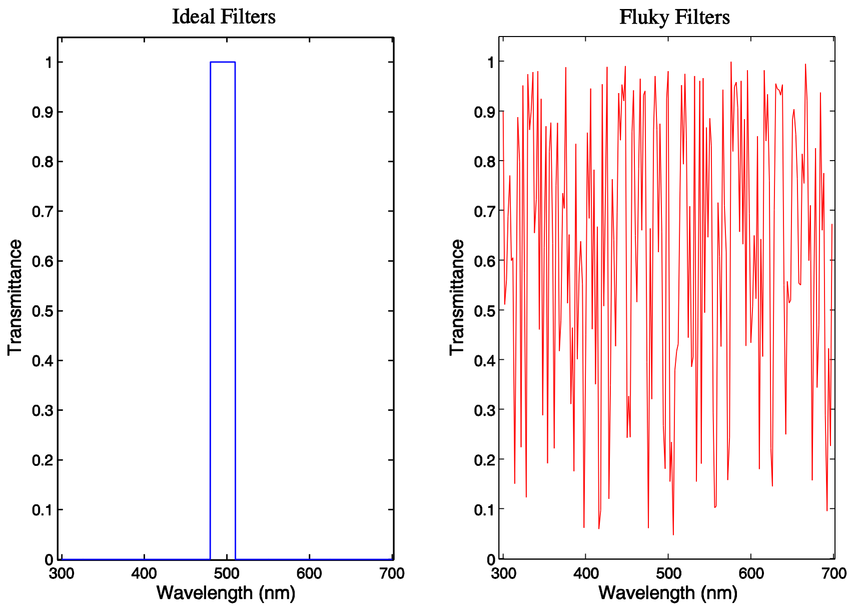

Figure: Pictorial comparison of transmittance between ideal brick wall and fluky filters

They claim that their invention is the first of its kind as an optical signal acquisition method, and it provides a significant new punch to the demanding spectrometer and optical imaging industries. The ideas are simple but general. It holds the potential to be applicable in many other signal acquisition applications including high resolution spectrometers, imaging and video systems. What was aimed at in their research article is to improve the resolution for a small family of portable spectrometers with a limited number of filter elements. Nothing, however, limits that the idea can also be used for an expensive spectrometer in a laboratory setting as well. There the goal can be shifted to break the barrier of resolution limit of a state-of-the-art spectrometer which employs a large number of filter elements. The same principle can be applied to improve the resolution of other imaging devices, including digital cameras, microscopes, radars, and ultrasound imaging devices.

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