Tunable Spectral Filter (TSF)

Technology Description

OPC's Tunable Spectral Filter (TSF) is essentially an interferometer that can be tuned to a specific frequency. As shown in Figure 1, the two beams, one reflecting from the fixed mirror and the other reflecting from the moving mirror interfere. The spectrum of the output beam can be modified by changing its optical path length difference, $\Delta t_{BS} - \Delta t_{air}$. The optical path Δt_{BS} is fixed while the piezo actuator moves the top mirror to change Δt_{air}.

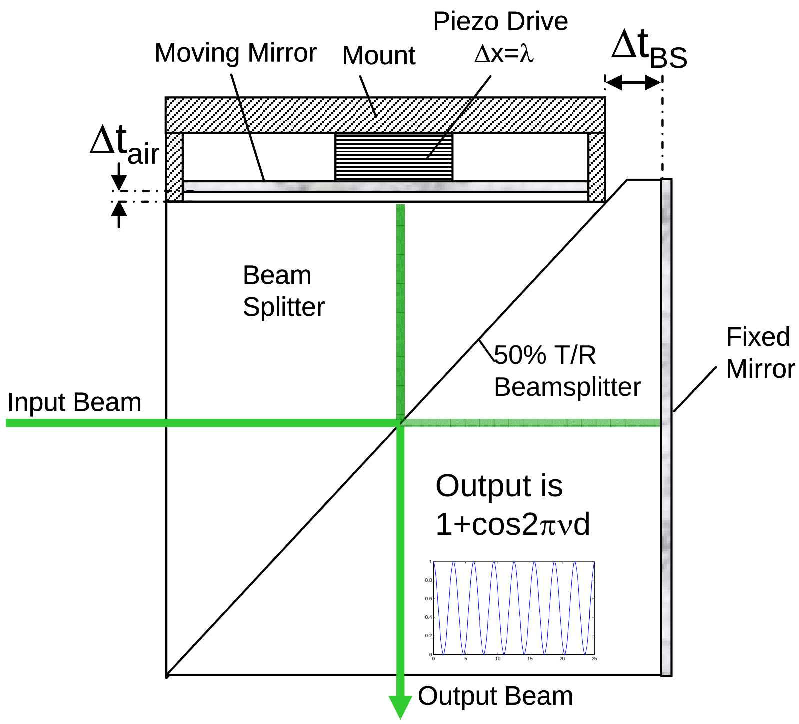

Figure 1. Tunable Spectral Filter (TSF) building block.

The transmission T given by

$$T = \frac{1}{2}(1 + \cos(2\pi\nu d))$$ **Equation 1**

where □ is the frequency of the incident radiation (cm^{-1}) and *d* is the Optical Path Difference (OPD) between the two reflection paths in the cube.

Cascading multiple filters leads to a filter stack with Spectral Response Function (SRF) which is the product of the response of the individual stages.

Asymptotically the transmission T versus wavenumber □ is given by

T(□) = sinc^2(□ □ □ □ □)   **Equation 2**

where $□_o$ is the line desired and □□ is the linewidth desired.

This is illustrated in Figure 2.

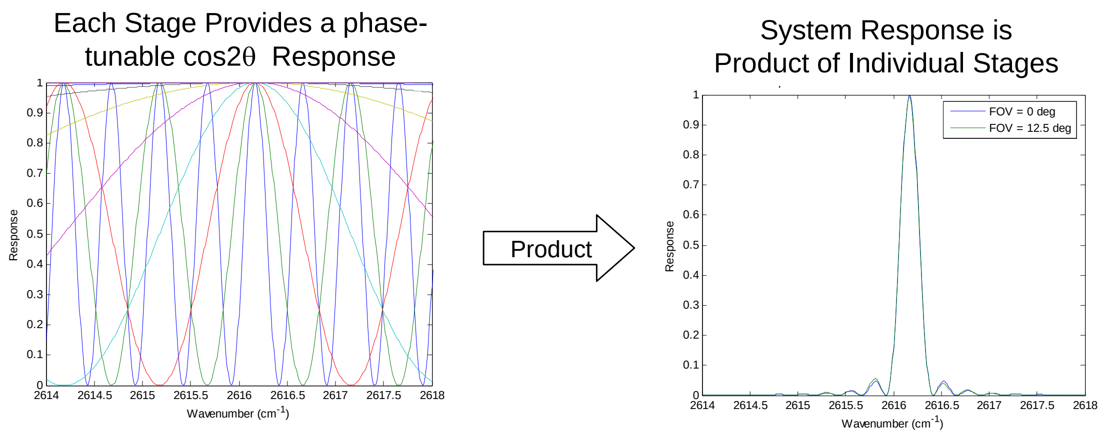

Figure 2. OPC TSF multi-stage transmission as a function of wave number.

One way to reduce the number of stages and still obtain a narrow linewidth filter is to use a tunable Fabry Perot filter to narrow the spectra of the light incident on the first stage as shown in Figure 3. With this approach, it is feasible to achieve a 0.1 cm-1 band using six stages.

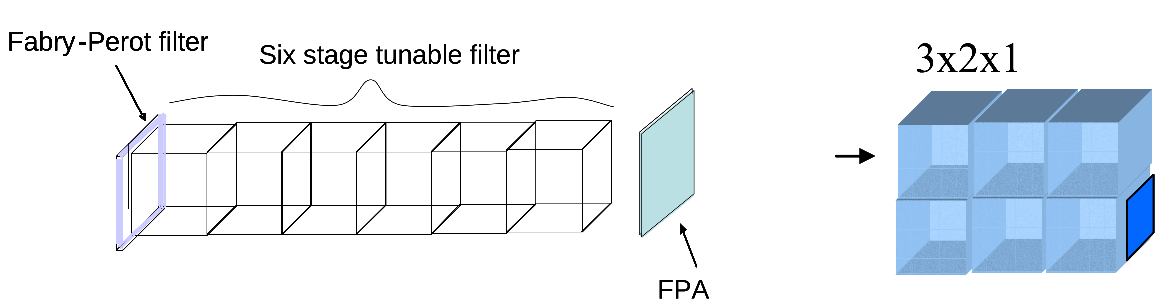

Figure 3. OPC TSF multi-stage with Fabry Perot tunable filter front-end (left). Folded arrangement of the same six stage filter (right).

Applications and Operational Capability

TSF is a general purpose tool for remote sensing, enabling detection and location of constituents of interest. A new kind of hyperspectral sensor equipped with TSF can capture 2D frames of the scene with the filter tuned to a selected spectral line, tunable at kHz rates. Image resolution is determined by FPA (e.g. 1K X 1K pixels). Spectral resolution up to 200X greater than for the best dispersion-based hyperspectral systems is readily achievable with selectable passband and center wavelength that affords high sensitivity detection.

Proprietary algorithms can quantify amount of constituent-of-interest present in the scene under view. Only spectral components of target constituents need to be queried. This means there is no data overload or full "hypercube" to deal with. Size and weight of the filter are dependent upon operating band.

The example shown in Figure 4 with the hydrocarbon methane (CH_4) spectrum illustrates the advantage of TSF's narrow line width capability. Methane is best detected using a detector with the very narrow (~ 0.1 cm-1) linewidth which the OPC TSF provides. Current state of the art hyperspectral sensor capability is 300X coarser.

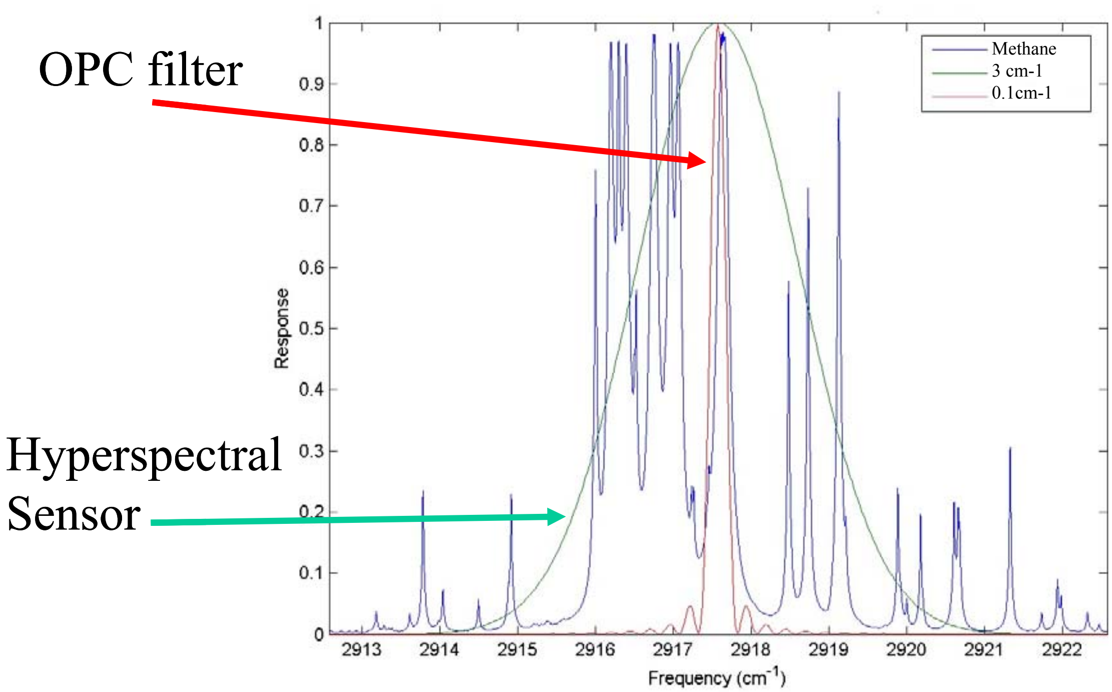

Figure 4. OPC TSF has the right linewidth to detect the spectral signature of methane (CH_4) whereas the state of the art hyperspectral sensor is 300x coarser.

Technology History and Status

TSF is patented technology protected by US Patent 6,580,509 assigned to OPC.

OPC has been developing the described tunable filter technology for 7 years. The core filter technology has been tested as a fixed (non-tunable) filter under three programs, first, as part of an imaging spectrometer in 2001, second and third, in two variants of stand-alone filter for AF Lasercom programs in 2006 and 2007, respectively.

We are now developing the tunable versions of the filter concept. There are two ongoing projects:

The first is under an SBIR contract sponsored by the Missile Defense Agency. We will have a TRL 4 version of a single stage tunable filter working at 35°K by the end of 2008 which switches between a short wave IR (SWIR) and a mid-wave IR (MWIR) spectral line at 500 Hz. Figure 5 shows hardware assembled to demonstrate the switching operation in the visible and near IR (NIR) regions of the spectrum.

The second is under internal research and development towards the assembly and demonstration of the TSF for mid wave IR operation. The testbed is shown in Figure 6. It consists of an imaging head with the TSF, an InSb FPA, readout electronics in a sealed dewar cooled by two Stirling coolers.

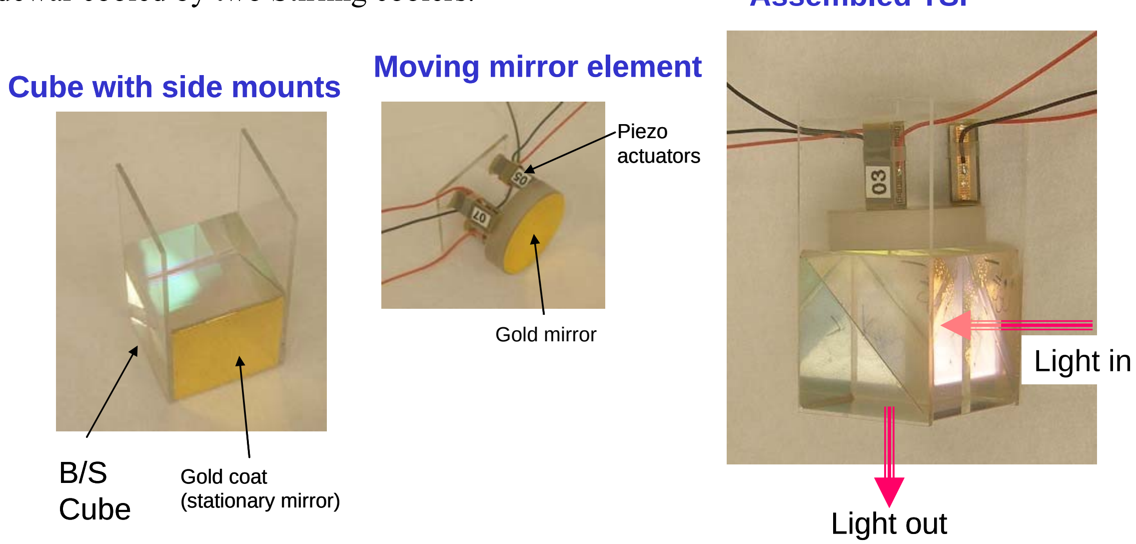

Figure 5. OPC TSF hardware. A single stage suitable for visible and NIR operation is shown.

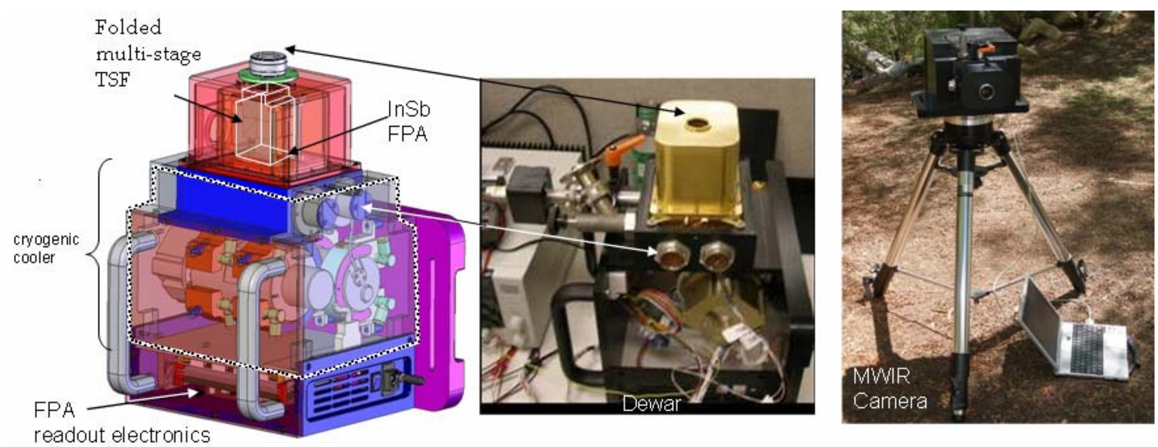

Figure 6. OPC TSF equipped MWIR camera testbed.