Pulse differential spectroscopy (PDS)  
is a spectroscopy sampling technique designed to extract blood spectra from bulk skin reflectance spectra in living mammals. The PDS technique taught in 9037206 is sufficient to compute extracted blood spectra, but it can be made more insensitive to 1/f noise (drift) and numerically robust, can be made less dependent on electronic signal amplification and can be made less sensitive to time dependent variation in the systolic/diastolic (heart beat) frequency.  
The existing technique produces a blood spectrum from bulk reflectance spectra by finding the spectra acquired during the peak of a systolic excursion and the peak of a diastolic excursion can computing the ratio between the two spectra.  This technique is susceptible to 1/f noise, or drift in the signal, that may occur due to skin movement or settling after a contact sampling probe contacts the skin.  The technique is also is inherently noisier than it could be in that most of the data acquired, the data sampled between the peaks of the systolic/diastolic excursions, is not used.  To address both of these issues, we propose using a fast Fourier transform (fft) processing technique.  This technique requires reflectance spectra to be acquired (at 100Hz or more) for time period greater than 2 heart beats (two sequential systolic/diastolic excursions).  The fft for each wavelength in the spectrum is computed for the spectra sampled during that time period.  The amplitude of each wavelength’s fft at the heartbeat frequency is defined as the blood spectrum. This approach utilizes all of the data acquired during the sampling time and, by ignoring the low frequency amplitude components of the fft, the resulting blood spectrum is insensitive to drift (1/f noise) in the sampled signal. Additionally, a "box car" fft approach can be used to produce blood spectra at the same sampling rate as the reflectance sampling rate.  For example, if the reflectance spectra sampling rate is 100Hz and the sampling time is 5 seconds, the first blood spectrum to be computed at 5.00s will be computed on the spectra 1 to 500.  The next blood spectrum computed at 5.01s will be computed on the spectra 2 to 501 and so on.  The resulting blood spectra can then be averaged as needed to further reduce noise.  
The existing technique requires at least one optical path through an external diffusely reflecting capillary bearing sample.  For the wavelength range considered, capillary bearing samples are highly diffusely reflecting.  As such, when considering the surface of the sample (skin), if the optical path launching photons into surface of the skin is in close proximity to the optical path receiving reflectance photons from the skin, the bulk received reflectance signal comes from photons whose diffusely reflected path is localized to the outer most layers of the skin (stratum corneaum and epidermis) which are typically void of capillaries.  Only a small fraction of the collected photons will have traveled into the capillary bed.  If the launch location is far from the receive location, the total return photons collected will be below the noise floor of the detector electronics.  The optimal separation for the wavelength range considered is between 50 and a few 100 microns to optimize the number of photons traveling through the capillary bed compared to the bulk reflectance photons collected. The result is the PDS signal and bulk reflectance signal optimized for the detector amplification and A/D dynamic range.  
The existing technique does not provide a means of determining the frequency of the systolic/diastolic cycle (hear rate). The addition of a NIR 750nm or VIS 540nm or 576nm LD to the array allows for a wavelength that has deep tissue penetration with high blood absorbance.  The FFT of this wavelength, sampled at the same rate as the SWIR wavelengths considered, will have a high signal to noise amplitude at the heartbeat frequency. Applying bounds to this wavelength’s fft frequency response of an upper and lower heartrate (say 180bmp and 25bmp), the highest amplitude in this bounded range can be identified as the heartrate and this frequency selected from the bulk reflectance ffts computed over the sampling time as the blood spectrum.  The addition of this deep tissue penetrating, high blood absorbance wavelength LD allows for varying heartrates to be accommodated with high SNR.  
The spectral sampling hardware described in 9037206 teaches the implementation of "at least one optical path which emits a plurality of narrow band pules having unique center wavelengths and each narrow band ...".  At the time of issuance, most LDs in the wavelength range of consideration had spectral emissions much wider than is sufficient for a calibration for any of the analytes of interest having specificity to achieve regulatory approval.  Optical filtering techniques available were comprised of absorbance and thin film transmission filters, fiber bragg filters or spectrographs.  Thin film filters or absorbance filters capable of filtering the bandwidth down to a 5nm full width half max (FWHM) typically have more than 0.01 nm/C thermal shift sensitivity.  Fiber bragg gratings require significant fiber length difficult to make compatible with a hand held device volume and are sources of stray light that must be mitigated with respect to the rest of the optical system. Spectrographs are difficult to make compatible with hand held device volumes with 5nm FWHM and <0.01nm/C thermal sensitivity.  Here, we propose using a volume bragg grating (VBG) for each laser diode, specifically designed for the center wavelength of interest from the LD, 5nm FHWM transmission and <0.01nm/C center wavelength sensitivity.  The VBG can be fabricated to have a collimating lens function hologram on the laser diode side of the VBG and a directional focusing lens function hologram on the LDA focal point side of the VBG.  Physical collimating lenses can replace the collimating lens function in the VBG as needed.  Physical directional focusing lenses can replace the directional focusing lens hologram in the VBG as needed.  Additionally, a narrow band grating can be etched onto each LD in the LDA in lieu of the narrow band filtering in the VBG and any combination thereof.

The hardware described in 8140139 appeals to a two each close in space spectroscopy system (TECS). The claims do not include this, as TECS was a provisional patent application that was abandond. The claims also do not explicitly describe an optical collection approach (collection of light from a source), an optical delivery approach (light from collection to the sample, ie skin), or an optical return approach (light from sample to detector(s)). The spirit of the TECS provisional was a referencing scheme that would allow the entire optical path of the device (not including the device/sample interface) to be referenced so no one component of the system could be a source of spectral variation, in particular 1/f drift. As described in the TECS provisional, typical reflectance spectroscopic referencing is achieved by placing a spectral reference material in front of the optical delivery output system (device/sample interface). TECS referencing, having only one detector for the optical return, implies that the two sources have to be time multiplexed. Two sources are desired for TECS so the optical paths can be just slightly different to achieve an embedded reference at the optical delivery output.

This approach is improved upon by reducing the number of sources to one and creating optical paths that are close in space using fiber bundles enclosed in a common thermal material. Along with reducing the number of sources needed to one (a complete LDA is considered a source), the TECS approach is improved upon by allowing the two close optical paths to simultaneously samples in time instead of time multiplexed. Additionally, as the TECS provisional alludes to, the number of detectors needed to achieve accurate referencing (as opposed to only stable referencing), doubles in the TECS scheme. This is improved upon by introducing a source whose output is within the detectors’ response band to act as a common detector reference source.

These improvements on 8140139 and the TECS scheme are summarized as follows:

1. A single LDA with wavelength filtering and wavelength coverage and LDA collection optics as described above
2. A beam splitter near the LDA collection optics’ focal point, passing a majority of the optical power to the focal point and a small fraction to a LDA reference detector (96%/4%)
3. Delivery optics that are comprised of 12 around 1 fiber bundles, using fiber diameters between 50 and 400 microns.
   1. All collection fibers of the delivery optics placed at the focal point of the LDA collection optics
   2. Delivery optic fiber bundles terminated for delivery to the sample, to a reference and to a control standard (the control standard is new)
      1. Reference and control material mounted at the surface of the device/sample interface
      2. Reference material being a thermally stable, highly diffuse reflecting material such alumina or Spectralon
      3. Control standard material being either a material as mentioned in ii above or with a spectral signature such a Dysprosium
   3. Return fibers of the delivery optic fiber bundles terminated at three separate detectors, each detector collecting light from the sample, reference and control fibers respectively
   4. Collection and return fibers potted in a thermally insulating encapsulant
4. All four detectors located in close proximity to each other
   1. A common reference LD (eg 1550nm) having an optical output path to each of the four detectors simultaneously.
5. The control/reference standard absorbance spectra evaluated against the analyte of interest to produce a synthetic analyte concentration that is measureable and variable as a function of the overall system stability