CLAIMS

WHAT IS CLAIMED IS:

1. A method of estimating the optical spectrum of a light beam, the method comprising:

projecting the light beam onto distinct spatial areas of a spectrometer, wherein each spatial area receives a different filtered version of the optical spectrum;

detecting a characteristic of the projected light beam at each of the distinct spatial areas of the spectrometer;

receiving a two-dimensional matrix in which each entry of the matrix provides a relationship between one or more spatial areas and each spectral feature, wherein the two-dimensional matrix is related to the input-output relationship of the spectrometer; and

estimating the optical spectrum of the light beam based on an analysis that uses both the detected light beam characteristics and the received two-dimensional matrix.

2. The method of claim 1, wherein

projecting the light beam onto distinct spatial areas of the spectrometer comprises:

separating the different filtered versions of the optical spectrum including sending each filtered version along a different direction or a different angle, and

projecting these separated filtered versions onto respective spatial areas.

3. The method of claim 1, wherein:

projecting the light beam onto distinct spatial areas of a spectrometer comprises producing a plurality of light beams that interfere with each other, and

the different filtered versions of the optical spectrum result from different optical resonances in the transmission of the spectrometer.

4. The method of claim 1, wherein detecting the characteristic of the projected light beam at the distinct spatial areas comprises detecting the intensity of the light beam along at least one radial path that extends through the projected light beam.

5. The method of claim 1, further comprising creating the two-dimensional matrix by:

interacting a test light beam with the spectrometer;

changing a spectral feature of the test light beam across a range of N distinct spectral features; and

for each spectral feature in the range,

detecting a characteristic of the test light beam at each spatial area; and

storing the detected characteristic of the test light beam at each of M spatial areas of the spectrometer as a column of the preliminary two-dimensional matrix, wherein the column is assigned based on the spectral feature and wherein the preliminary two-dimensional matrix captures the input-output relationship of the spectrometer; and

calculating the two-dimensional matrix based on the preliminary two-dimensional matrix;

wherein the number of rows of the two-dimensional matrix and the number of columns of the preliminary two-dimensional matrix equals N, and the number of columns of the two-dimensional matrix and the number of rows of the preliminary two-dimensional matrix equals M.

6. The method of claim 5, wherein estimating the optical spectrum of the light beam comprises performing matrix multiplication between the two-dimensional matrix and the detected light beam characteristics.

7. The method of claim 5, wherein the number N of distinct spectral features determines a resolution of the estimated optical spectrum.

8. The method of claim 1, further comprising:

creating the two-dimensional matrix by calculating a pseudoinverse of a preliminary two-dimensional matrix, wherein the preliminary two-dimensional matrix captures the input-output relationship of the spectrometer; and

storing the two-dimensional matrix;

wherein estimating the optical spectrum of the light beam comprises performing matrix multiplication between the two-dimensional matrix and the detected light beam characteristics.

9. The method of claim 8, further comprising reducing an impact of noise by reducing the components of the matrix product for which contributions from the noise exceed contributions from the signal.

10. The method of claim 1, further comprising storing the detected characteristics of the projected light beam in an array, wherein the number of rows of the array corresponds to the number of rows of distinct spatial areas of the spectrometer in one spatial direction and the number of columns of the array corresponds to the number of columns of distinct spatial areas of the spectrometer in another spatial direction.

11. The method of claim 1, further comprising calculating a spectral feature based on the estimated optical spectrum, wherein the spectral feature includes one or more of a wavelength and a bandwidth.

12. A metrology apparatus comprising:

a spectrometer in the path of a light beam, the spectrometer comprising:

a spectrum dispersing device configured to separate the light beam into different filtered versions of the optical spectrum; and

a detector in the path of the projected light beam and defining distinct spatial areas, the detector being configured to receive a different filtered version of the optical spectrum at each spatial area and to detect a characteristic of the projected light beam at each distinct spatial area; and

a control system connected to the spectrometer and configured to:

receive a two-dimensional matrix in which each entry of the matrix provides a relationship between one or more spatial areas and each spectral feature, wherein the two-dimensional matrix is related to the input-output relationship of the spectrometer;

analyze the detected light beam characteristics and the received two-dimensional matrix; and

estimate an optical spectrum of the light beam based on the analysis.

13. The metrology apparatus of claim 12, wherein each spatial area is a surface made up of one or more imaging elements of a detector.

14. The metrology apparatus of claim 12, wherein the spectrum dispersing device includes an interference optical apparatus that comprises:

an etalon configured to angularly separate the light beam into the different filtered versions of the optical spectrum by producing a plurality of light beams that interfere with each other, and

a lens configured to project the different filtered versions onto the distinct spatial areas of the detector;

wherein the spatial areas of the detector are arranged along a radial direction from a center region.

15. The metrology apparatus of claim 12, wherein the detector includes an array of photodiode detectors that extend along one direction.

16. The metrology apparatus of claim 15, wherein the control system includes memory configured to store the detected characteristics of the projected light beam in an array, wherein the number of rows of the array corresponds to the number of rows of distinct spatial areas of the detector in a first spatial direction and the number of columns of the array corresponds to the number of columns of distinct spatial areas of the detector in a second spatial direction.

17. The metrology apparatus of claim 16, wherein the first spatial direction is a radial direction and the second spatial direction is perpendicular to the radial direction.

18. The metrology apparatus of claim 12, further comprising:

a test light source configured to produce a test light beam, wherein the spectrometer interacts with the test light beam; and

a spectral feature actuation apparatus controlling a spectral feature of the test light beam.

19. The metrology apparatus of claim 18, wherein:

the spectral feature actuation apparatus is configured to change a spectral feature of the test light beam across a range of N distinct spectral features while the test light beam interacts with the spectrometer;

the detector is configured to detect a characteristic of the test light beam at each spatial area; and

the control system is connected to the test light source and the spectral feature actuation apparatus, and is configured to create the two-dimensional matrix by: for each spectral feature in the range, storing the detected characteristic of the test light beam at each of M spatial areas of the spectrometer as a column of the preliminary two-dimensional matrix, wherein the column is assigned based on the spectral feature and wherein the preliminary two-dimensional matrix captures the input-output relationship of the spectrometer.

20. The metrology apparatus of claim 18, wherein the test light beam has a bandwidth that is 5-500,000 times smaller than the bandwidth of the light beam.

21. The metrology apparatus of claim 18, wherein the test light source includes a single frequency all-solid-state laser.