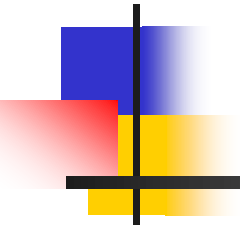


Building a Spectrometer

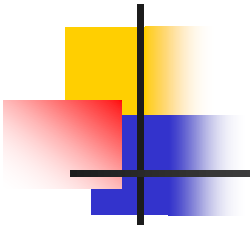
Dr. Chen-Hanson Ting
Silicon Valley Forth Interest Group
8/26/2017

Spectroscopy

Spectroscope
Visual observation of spectra
Spectrograph
Record spectra as photographs
Spectrometer
Record spectra electronically
Spectrophotometer
Record and analyze spectra electronically for quantitative analysis

CD Spectroscope

CD Spectroscopes



CD Spectrograph

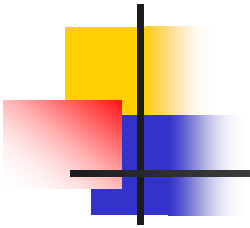
Spectrographs are spectra recorded on photographic plates.

Modern digital cameras have millions of pixels and are capable of recording good spectrographs.

Digital spectrographs still need "development".

My Spectrograph

My Spectrograph



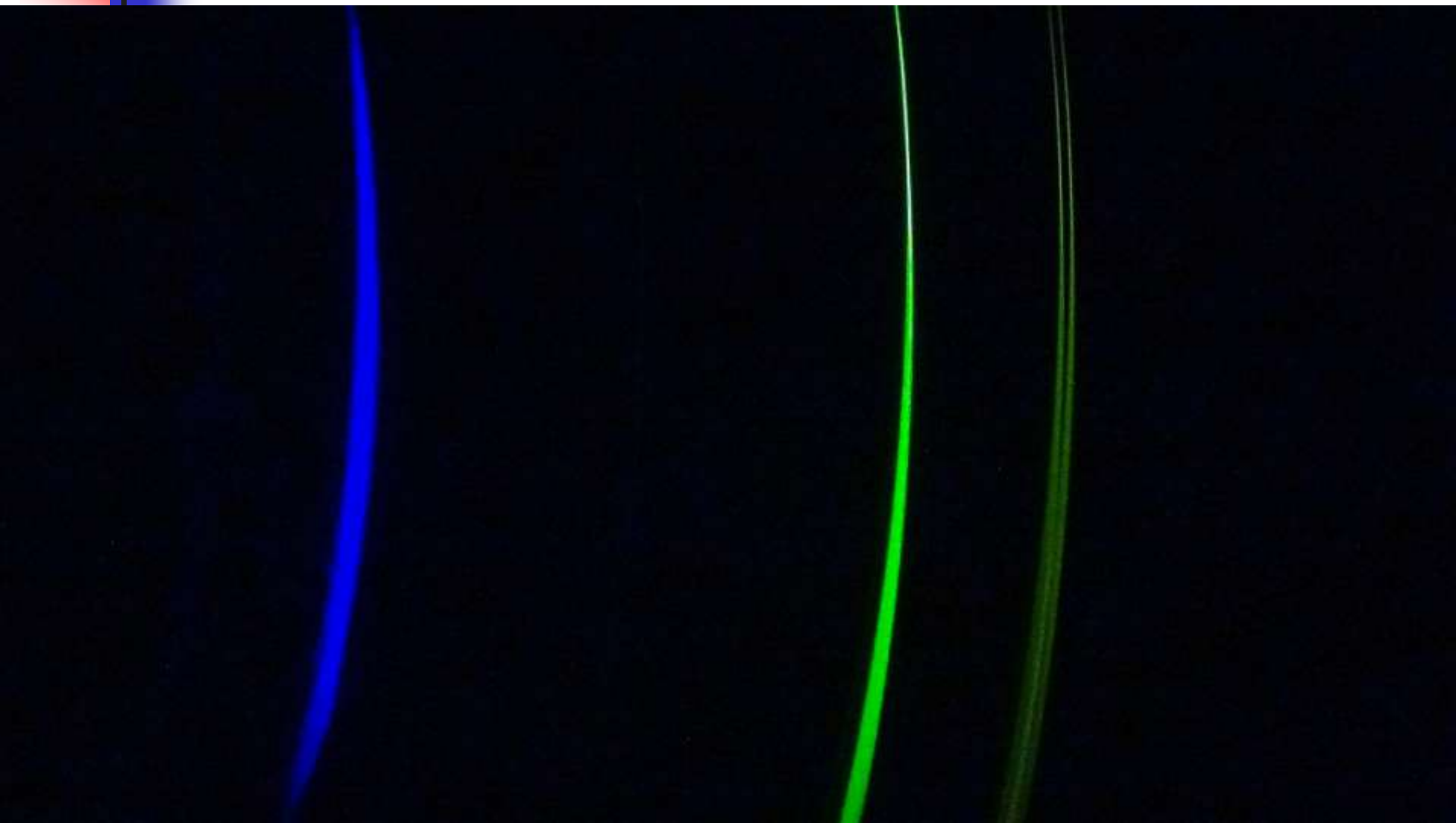
CD Spectroscopy

CDROM has very accurate ruling, and can be used as precision grating for spectroscopy.

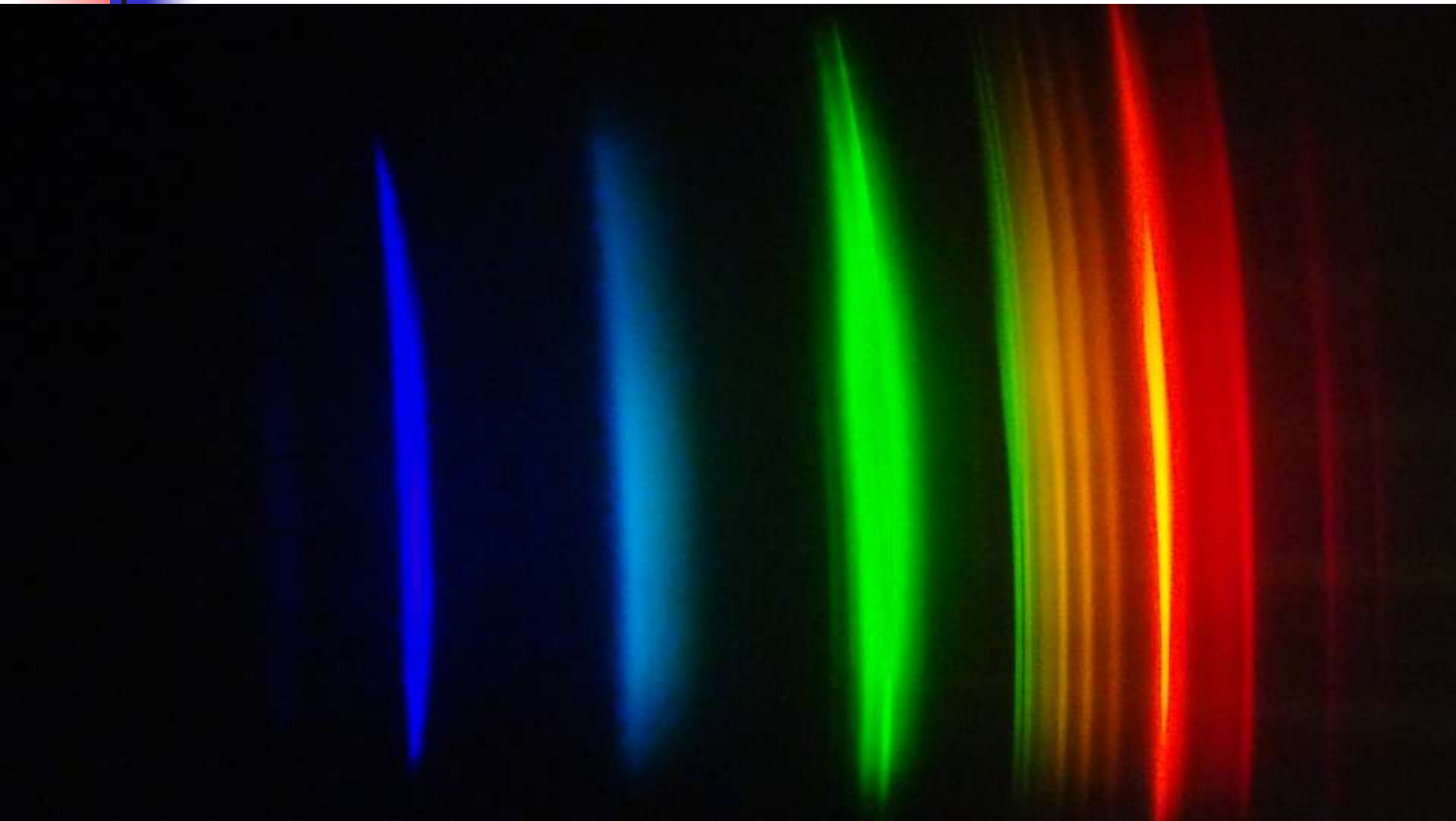
Digital cameras are very sensitive and accurate area detectors for spectrographs and for spectrometer.

The only drawback in CD spectroscopy is that the spectral lines are curved.

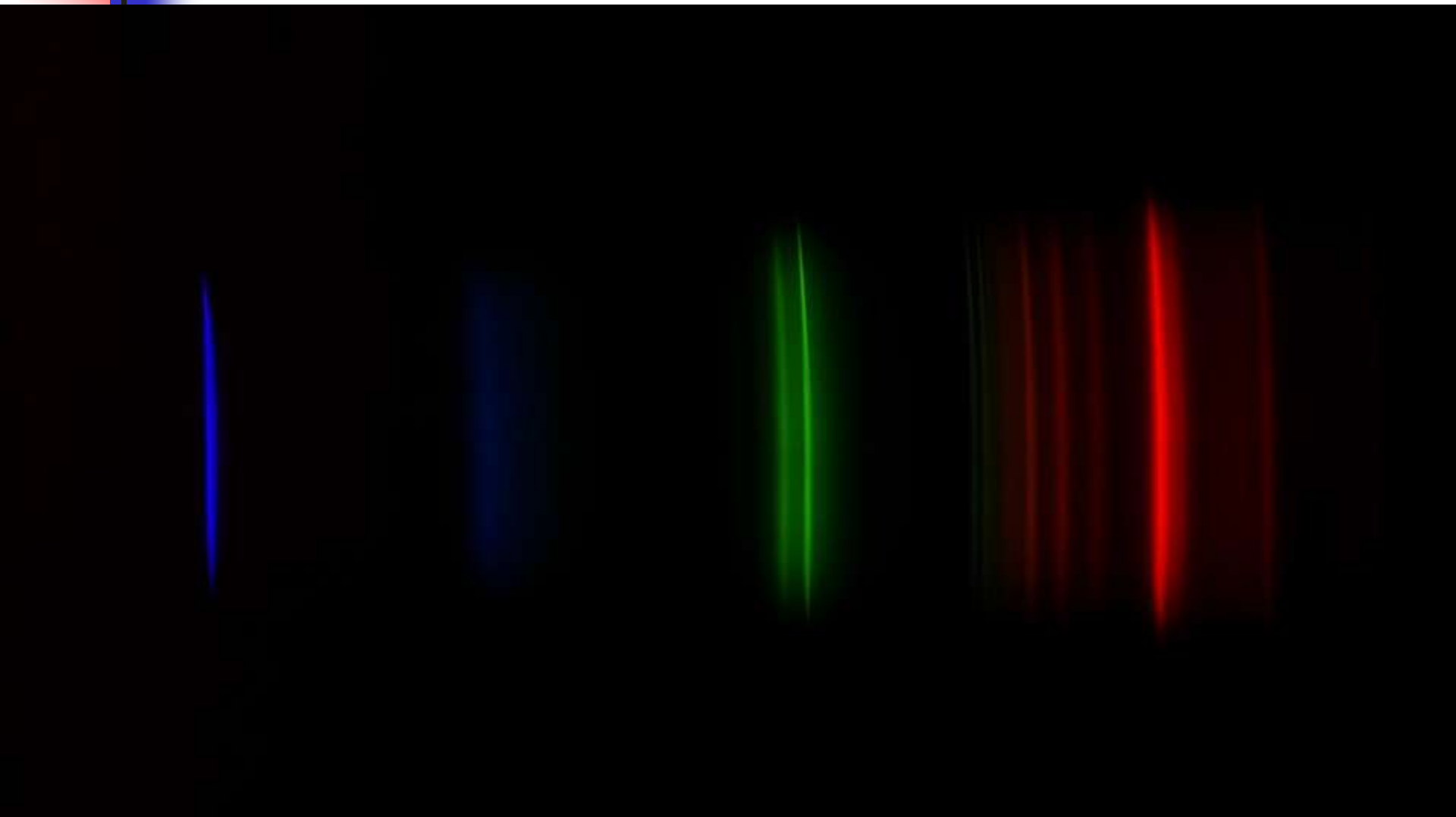
Mercury Spectraph



Compact Fluorescent Lamp Spectrograph



Compact Fluorescent Lamp Spectrograph



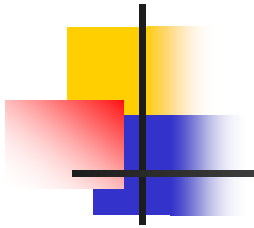
Spectrometer

Electronic images recorded by digital camera can be processed to become a spectrometer.

Curved spectral lines must be straightened.

Straightened spectral lines must be integrated vertically to form accurate spectrum.

Straighten Curves

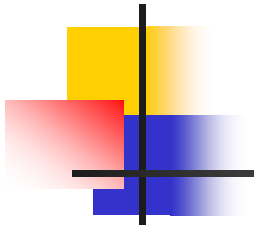


Assume spectral lines are on concentric circles.

Take 3 points on a spectral line to determine the center of all concentric circles.

Move pixels on a concentric circle to a straight line.

3 Points on a Circle



A(x1,y1); B(x2,y2); C(x3,y3)

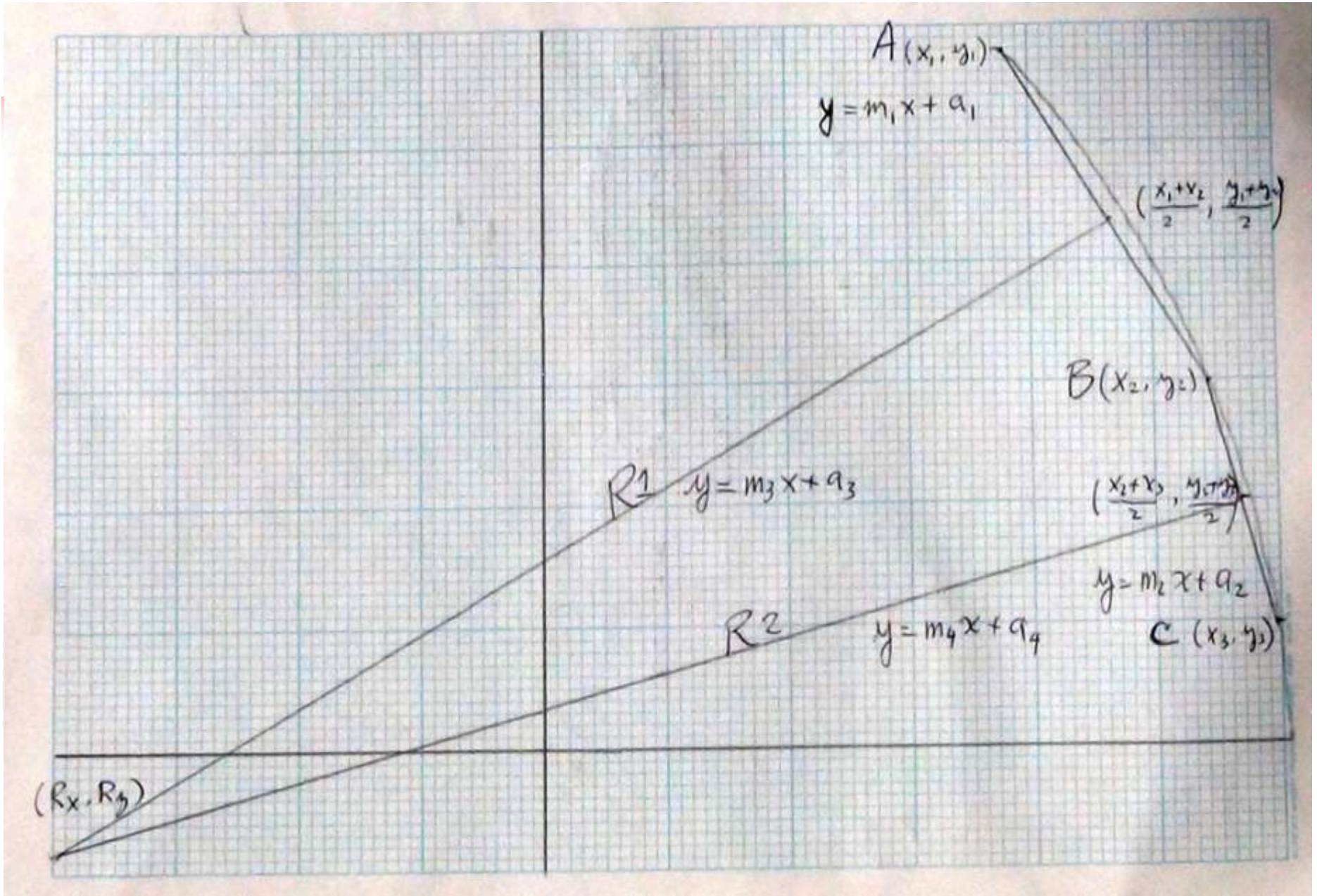
AB: $y=h1*x+a1$

$h1=(y2-y1)/(x2-x1)$

BC: $y=h2*x+a2$

$h2=(y3-y2)/(x3-x2)$

3 Points on a Circle



2 Bisecting Lines

M1: $y=h3*x+a3$

$h3=-1/h1$

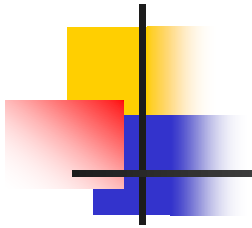
$a3=(y2+y1)/2 + (x2+x1)/2/h1$

M2: $y=h4*x+a4$

$h4=-1/h2$

$a4=(y3+y2)/2 + (x3+x2)/2/h2$

Center of Circle



R(x4,y4) is at intersect of M3 and M4:

$$y4=h3*x4+a3$$

$$y4=h4*x4+a4$$

Solve these two equations to get center of circle:

$$x4= -(a4-a3)/(h4-h3)$$

$$y4=h3*x4+a3$$

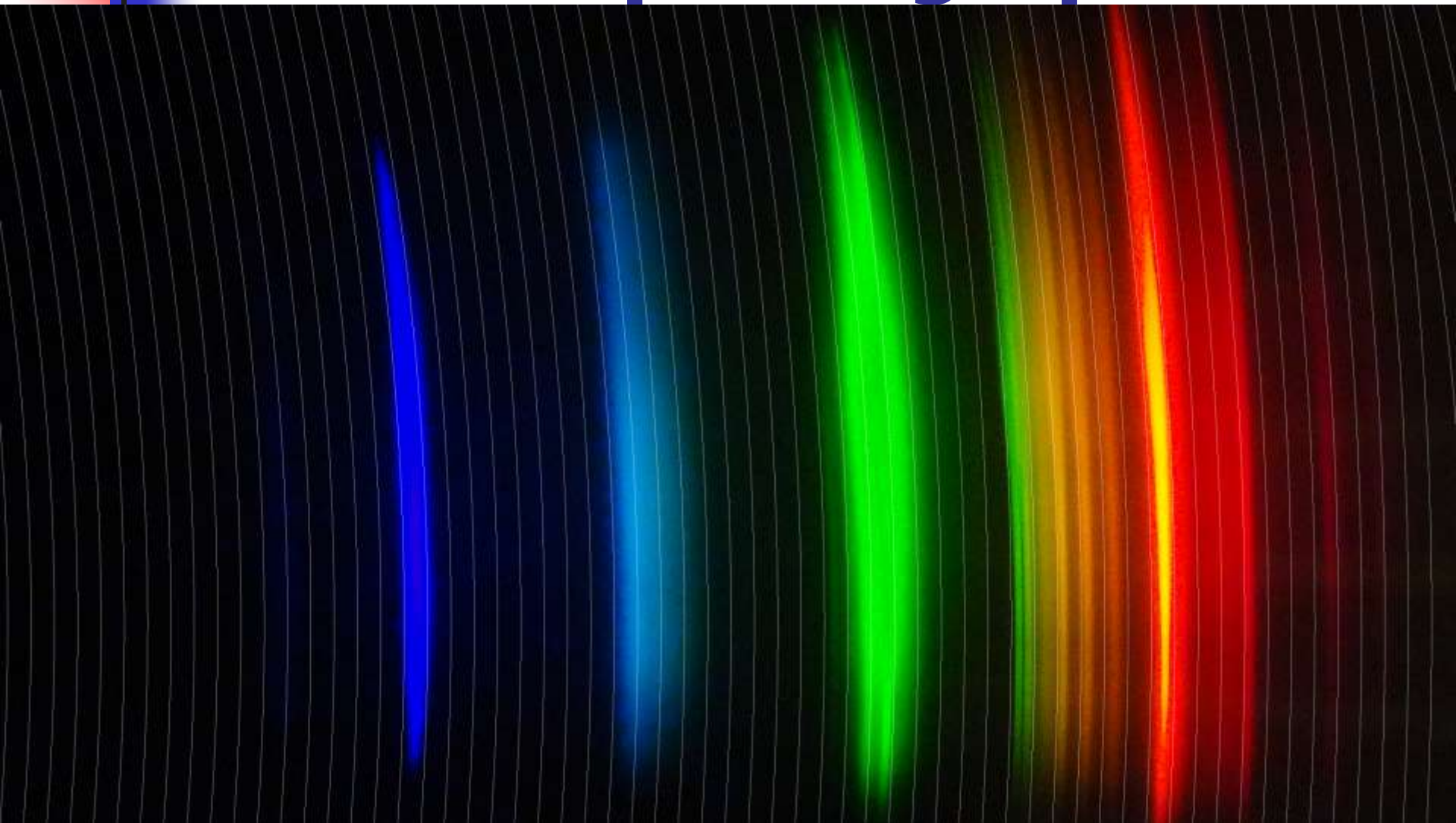
Center of Circle

A spreadsheet was used to compute centers of circle for spectral lines in two spectrographs of compact fluorescent lamps.

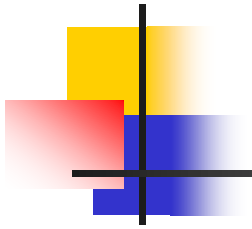
Straighten Spectral Lines

1. Scan top row in a spectrograph.
2. For each pixel, draw a circle over spectrograph.
3. Read each pixel on circle, and store it in the corresponding pixel in a vertical column.
4. Sum all pixels to form one spectral trace.

Concentric Circles on a Spectrograph



Draw a Circle in 1st Quadrant



For point (x,y) on a circle of radius R

RR=x*x+y*y=RR0

Move y to y-1, RR is reduced to

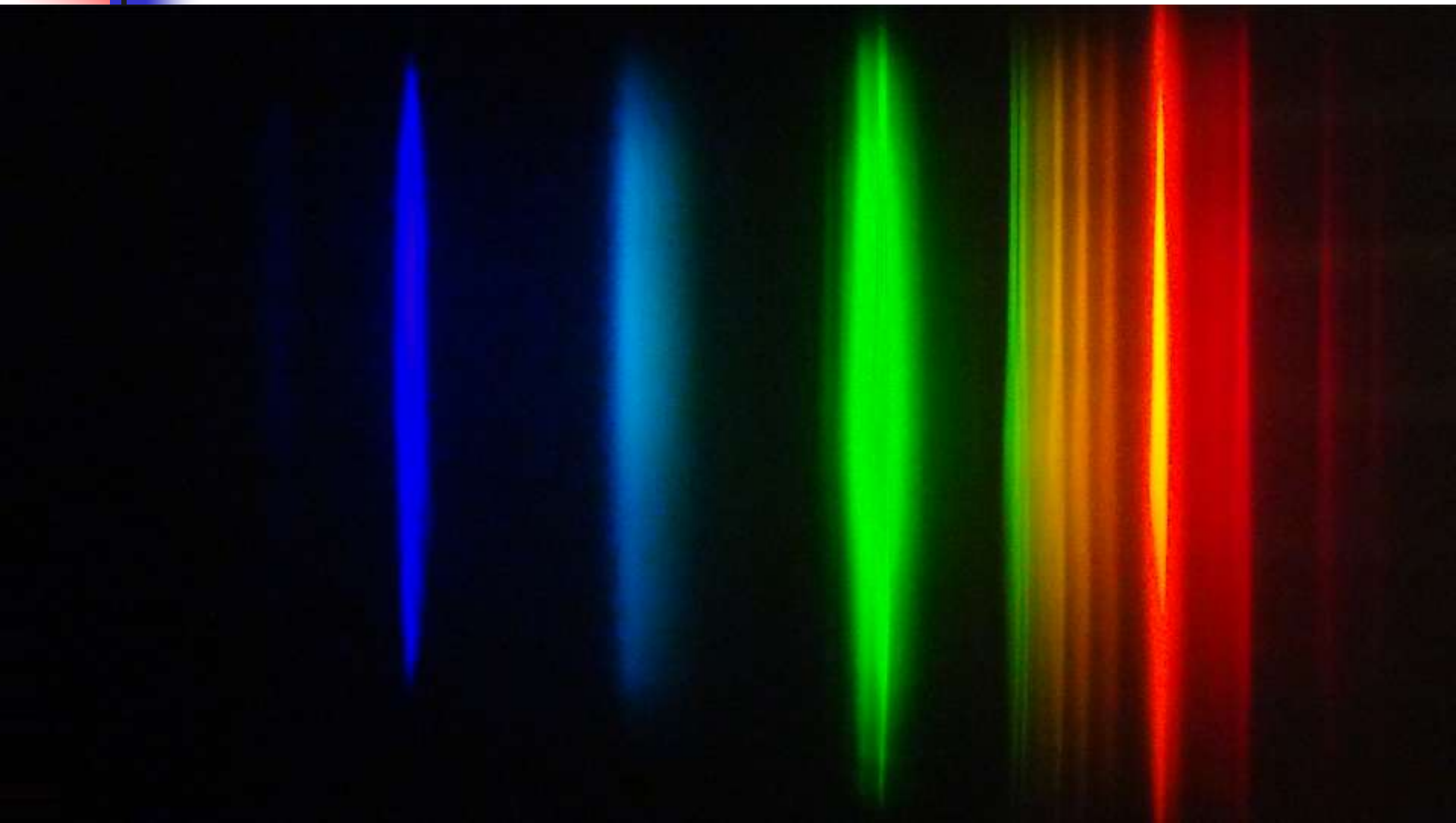
RR-2y+1

Move x to x+1, RR is increased to

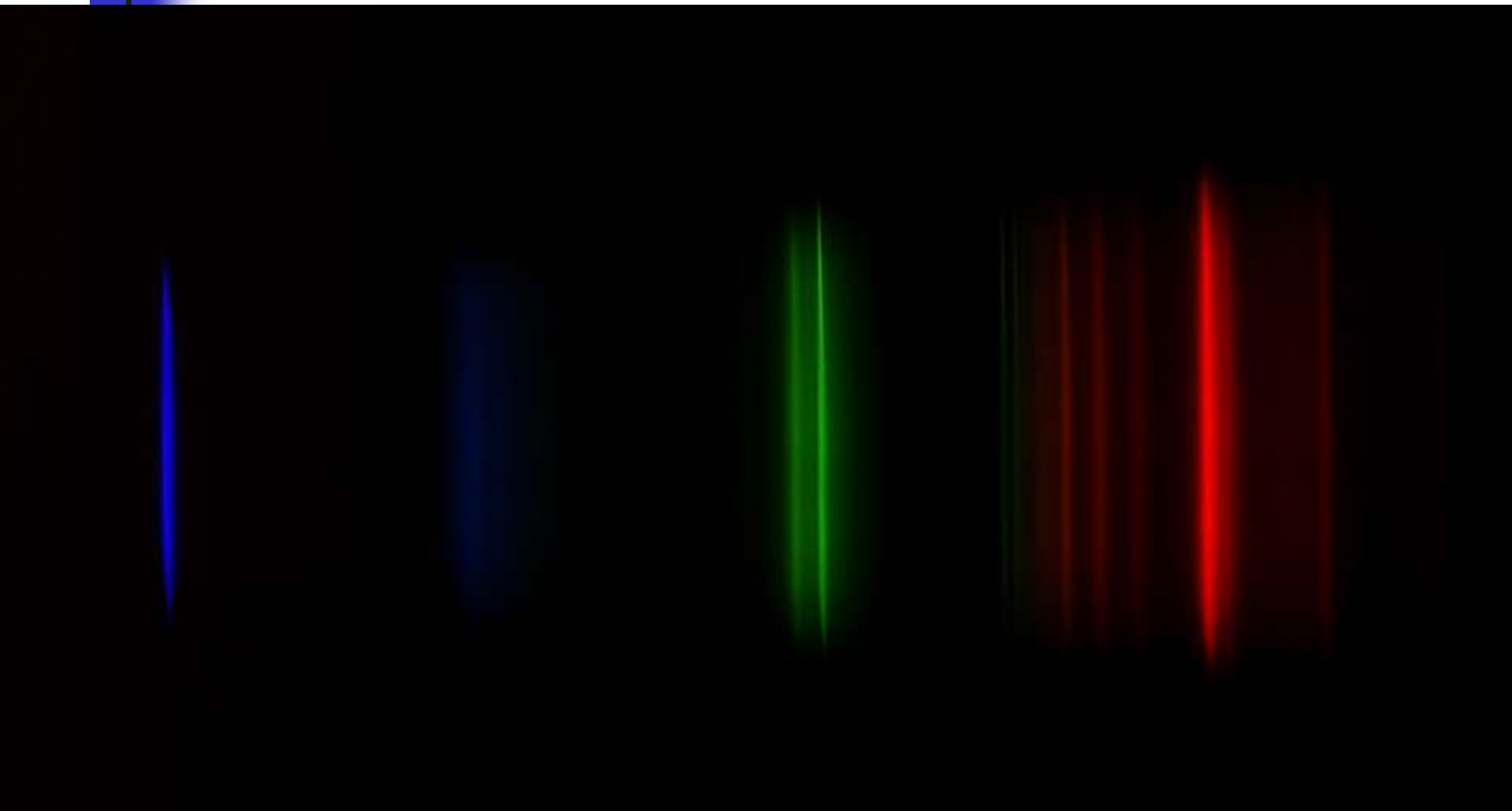
RR-2y+1+2x+1

Increment x, until RR>RR0, then reduce it by 1. New (x,y) is always inside the circle, and RR is always x*x+y*y.

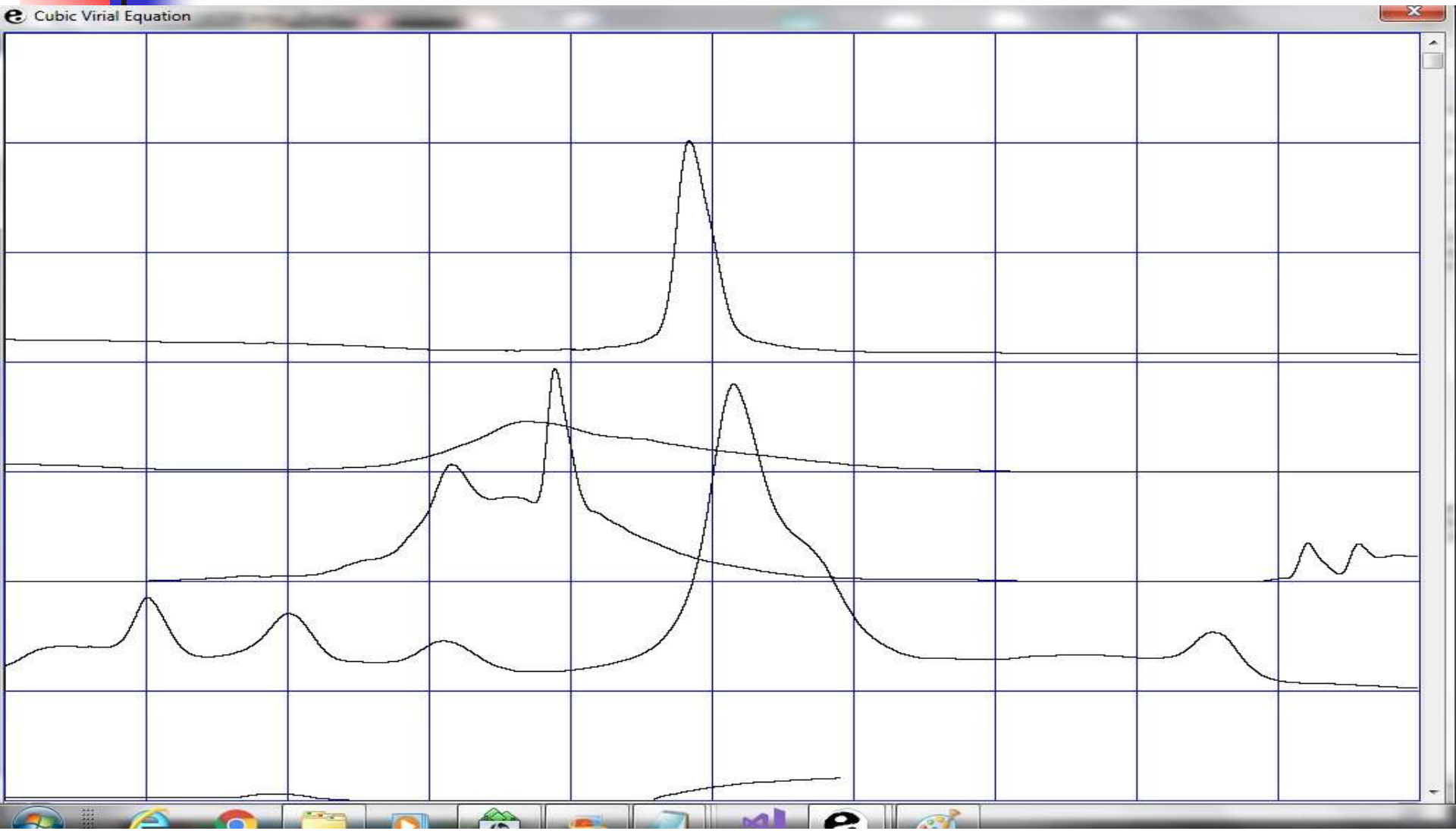
Straightened Spectrograph



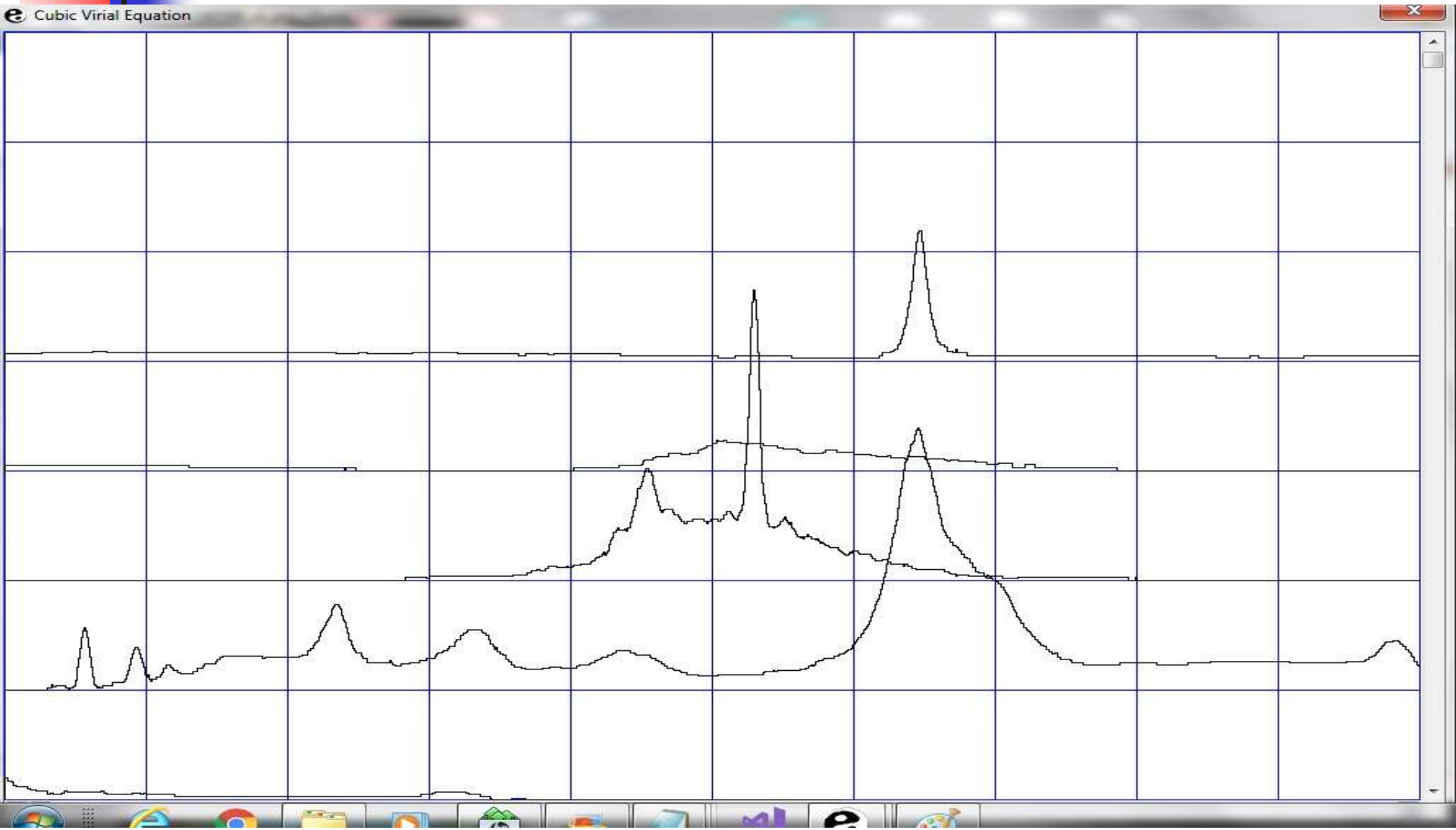
Straightened Spectrograph

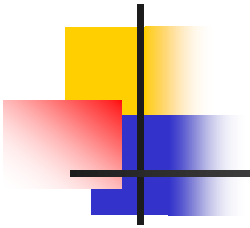


Plot a Spectral Trace



Plot a Spectral Line



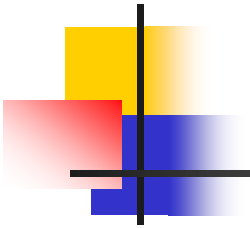


Spectrophotometer

Accurate measurement of spectral line intensity for quantitative analyses of atoms and molecules.

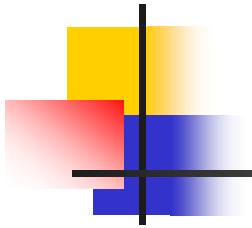
Once we have a spectrometer, spectrophotometer is just another software layer.

Digital Camera is No Spectrometer Yet

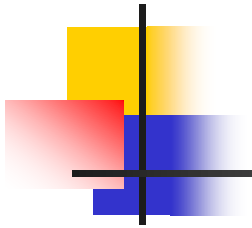


To make a spectrometer, I need intimate control of camera, focal length, aperture, exposure, and instant downloading image.

USB3 cameras will allow these capabilities, but they are not yet available commercially.



Questions?



Thank you very much.