Experiment 1:

Optical Measurements

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Motivation: Rainbow

Rainbow phenomenon, result of:

- Minimal deflection angle off a water drop
- Refractive index dependence on the wavelength

Use the **minimal deflection angle** phenomenon to obtain the optical parameters of a disk, a prism and a diffraction grating with **superb precision**

The Leading Principle: Extremum Experimental Method

- Ordinary experimental method:

  - Measure experimental variables

  - Extract physical quantity: solving equations, regression

  - Sensitive to errors in **all** experimental variables

- Alternative method: measure at an extremal setting

  - Achievable with great precision

  - Supplies further equations: solve for less-easy-to-measure variables

  - Extract physical quantity using **subset** of the experimental variables

Parts of the Experiment

Part A

- Disk, Mimicking the rainbow effect, with one wavelength
- Finding refractive index with **superb precision**
- Multiple orders
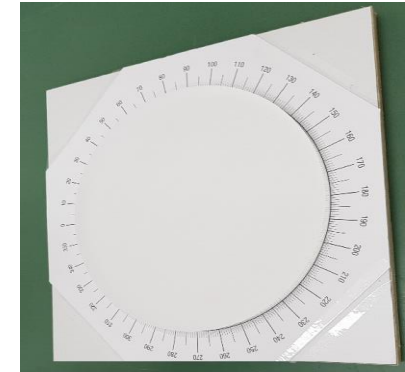
Part B

- Diffraction grating
- Finding the ratio λ/d with **superb precision**
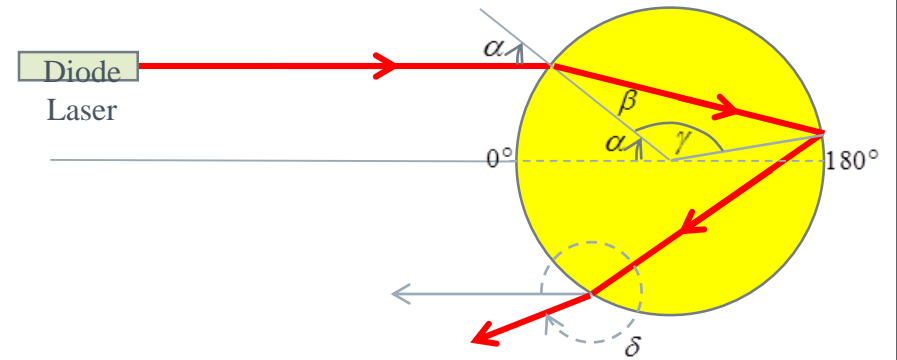- Multiple orders

Part C

- Prism
- Finding refractive index with **superb precision**

Part A: The refractive index of a disk

- Measure deflection angle as a function of the incident angle

- **Snell's law** with regression is possible, suffers from **bad precision** for the incident angle due to the **width of the ray**

- **Minimal deflection angle** is easy to find despite the width of the ray

- Refraction angle only is enough at the minimal deflection angle

Part A: The refractive index of a disk

- Use **multiple reflections** to find the refraction angle with high precision

- Obtain the refractive index with super precision

- Analysis is possible with "**higher order rainbows**" as well

- Perform the same analysis on different rainbow orders to get an estimate on the error of the refractive index (<0.5%)
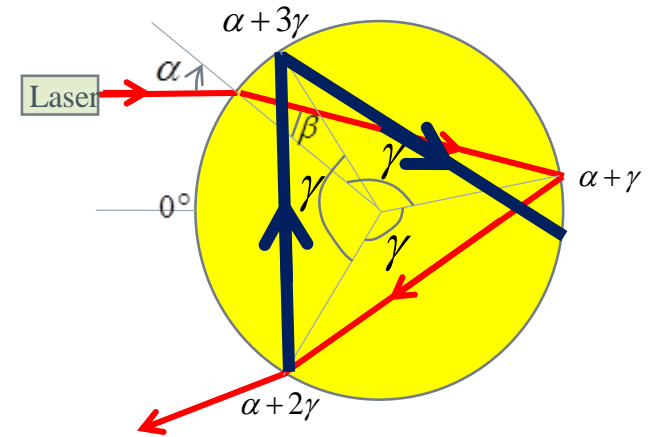
Part B: Diffraction grating parameters

- Regular method requires knowing the incident angle α which is difficult to measure with good precision

- Finding the incident angle where the maximum of order m is at a minimal deflection angle, gives a second equation which allows to avoid measuring the incident angle

- The students are required to repeat the measurements at various maxima orders
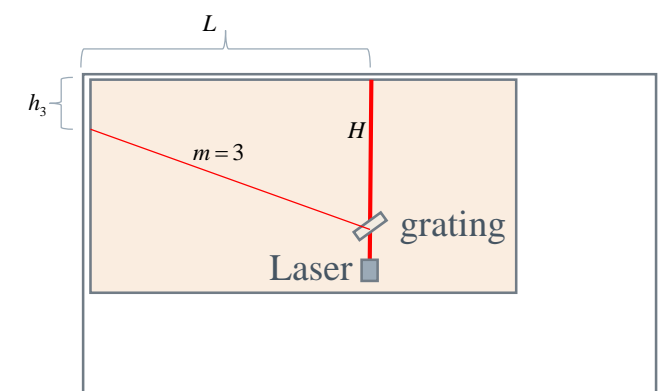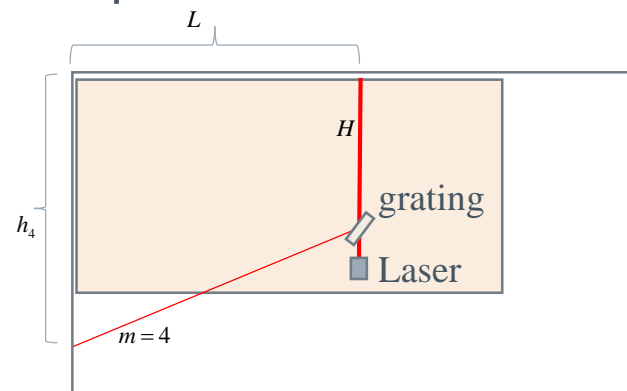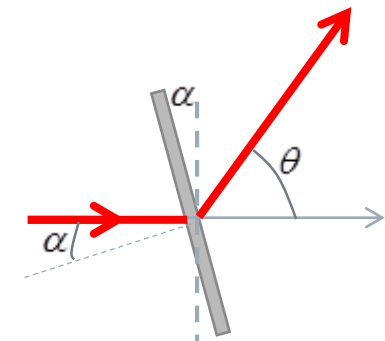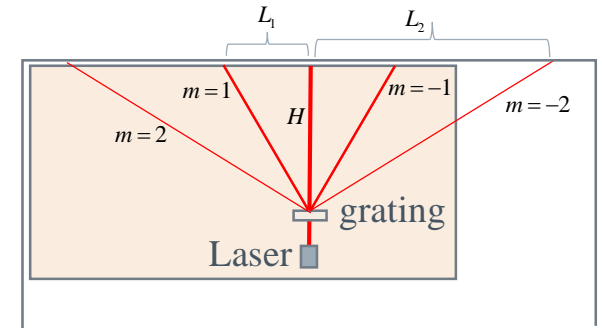
Part C: The refractive index of a prism

- Again, measuring the incident angle is difficult

- Using the minimal deflection angle allows to relate the incident angle and the deflection angle, overcoming the difficulty in measuring the incident angle
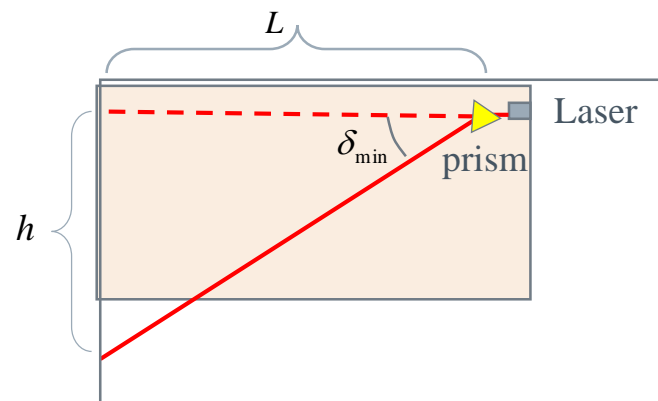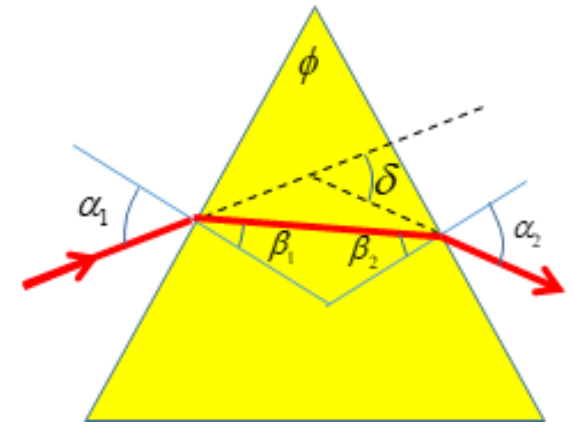
Summary

- **Original** and **sophisticated** experimental method

- **Superb precision** with **minimal obstacles**

- Direct methods – **possible but less accurate**

- Students are tested for: **Creativity, Physical understanding, Experimental technique**