Physics Lab
ETH zürich

D PHYS

Ultrasound

Abstract:

Goal of the experiment:
measure the speed of sound in water

Idea:
measure the wavelength of sound waves for a given frequency using different optical methods (diffraction and Schlieren method)

Background of experiment:

Ultrasound: a sound wave with a frequency above ~ 20 kHz (non-audible for humans)

Sound waves in gases and liquids propagate as compression wave, resulting in density changes and thus refractive index changes

The governing equation is the **wave equation:**

$$\frac{\partial^2 \varphi}{\partial t^2} - c^2 \triangle \varphi = 0$$

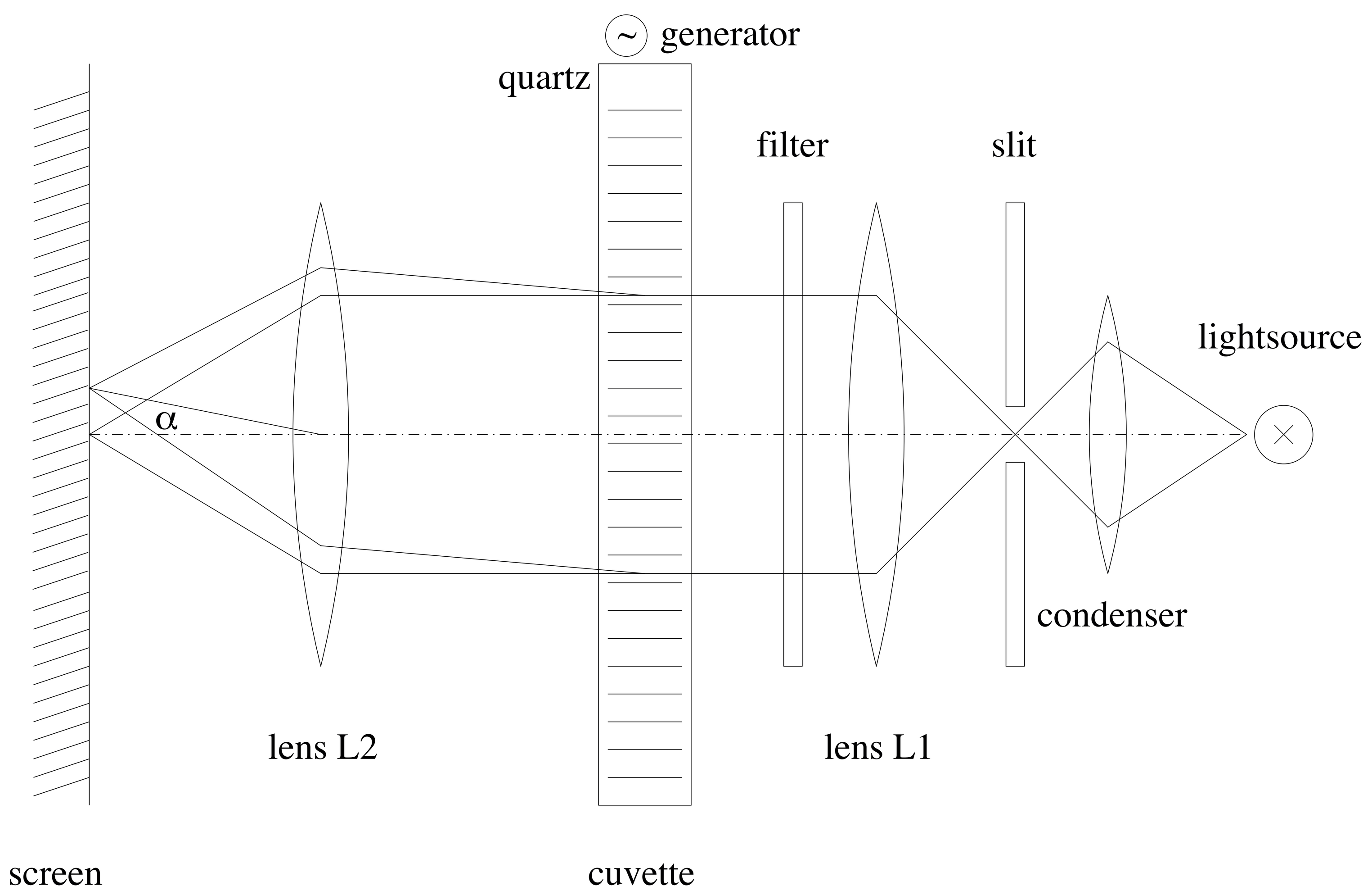
A possible solution: **plane wave**

$$\varphi(\vec{x}) = \varphi_0 \cdot e^{i(\vec{k}\vec{x} - \omega t)}$$

The interference effects by diffraction of plane waves traversing through grating are described by **Bragg condition:**

$$\sin(\alpha_n) = \frac{n\lambda}{d}$$

Experimental setup: diffraction method

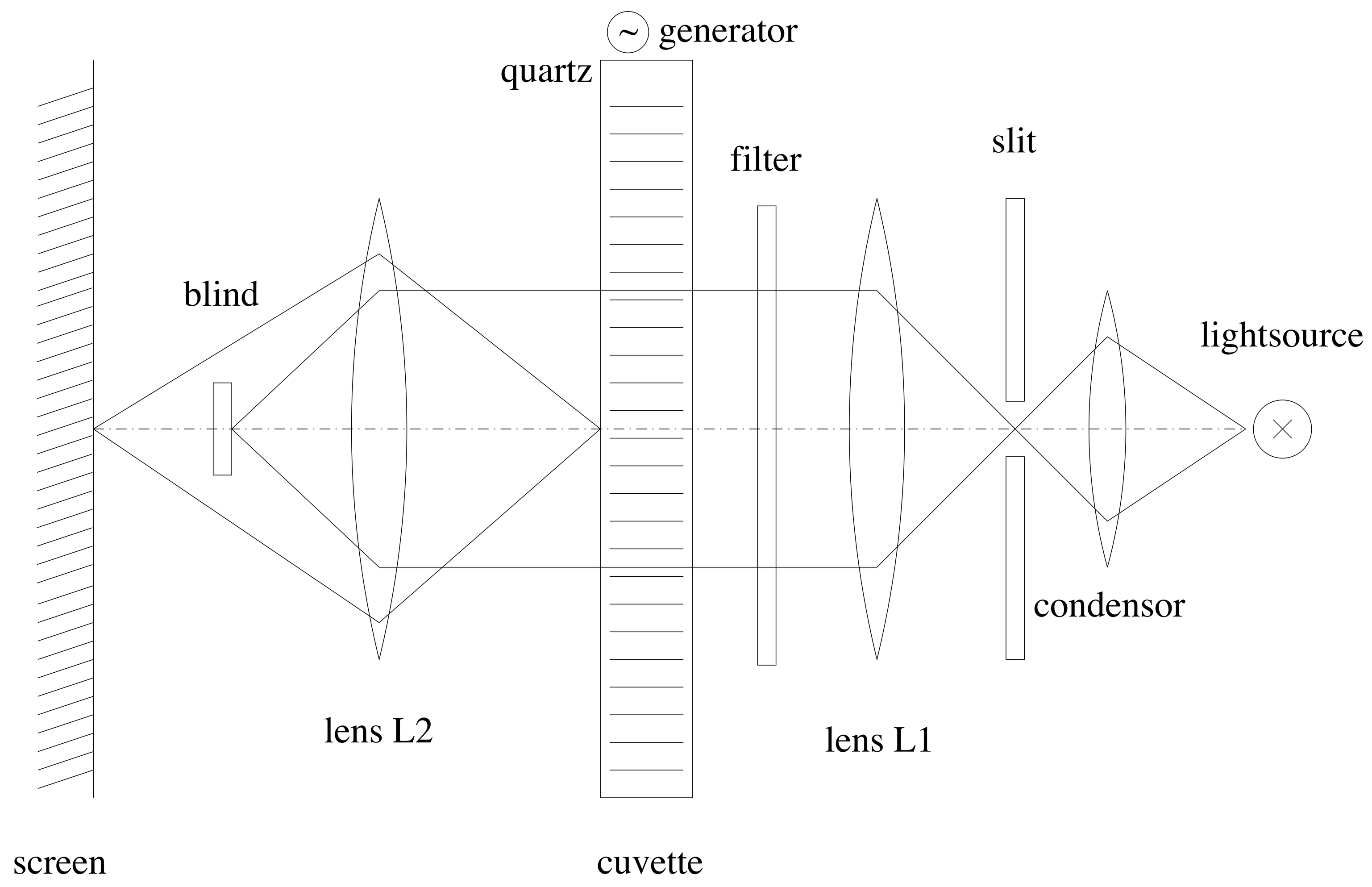


Setup for the diffraction method with two lenses

Setup:
- lightsource: green LED
- filter: narrow band filter
- cuvette contains deionised water
- ultrasound waves from Quarz using HF-generator (1.3 or 2 MHz) via Piezo effect
- measurement with one or two lenses
- screen or camera for observation of diffraction pattern

Idea:
- ultrasound creates a phase grating in water through standing wave if cuvette has the right length (n*λ/2)
- grating leads to a diffraction pattern of the incident light from which the ultrasound wavelength can be calculated using Bragg condition

Experimental setup: Schlieren method

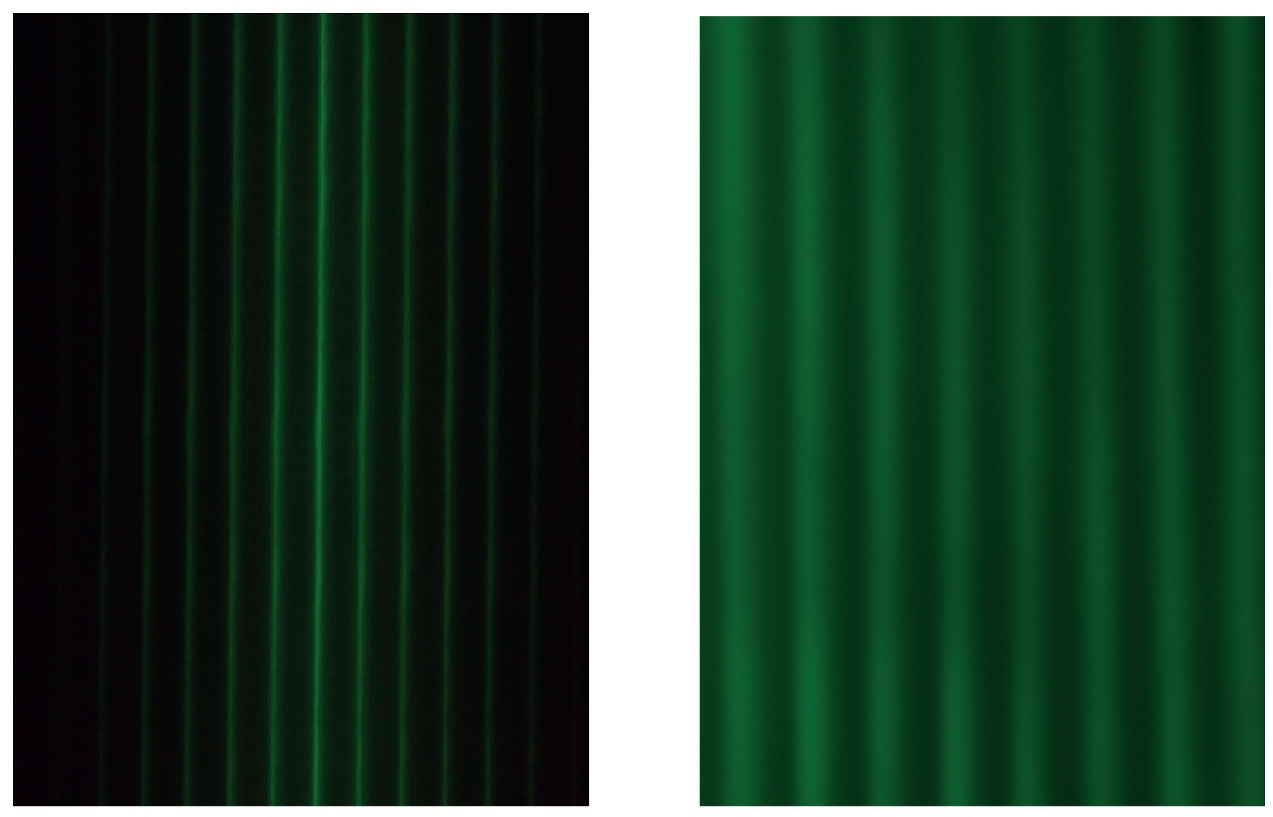


Setup for the Schlieren method with two lenses

Setup:
- measurement setup similar to diffraction method
- difference: blind in front of screen to block light which is not scattered by standing wave
- measurement with one or two lenses possible (one lens: higher magnification possible, but less contrast)

Idea:
- direct imaging of grating on screen
- blind necessary to block unscattered light
- lens L2 focuses image of the grating on the screen/camera
- advantage: higher magnification possible than using diffraction method

Results:



Typical images attained using the diffraction method (left) and the Schlieren method (right)

Evaluation of images:
- extraction of distance between maxima from the images
- for given excitation frequency of quartz: calculate wavelength of ultrasound from distance
- speed of sound then given by:

$$c_S = \nu_S \cdot \lambda_S$$

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