

PGF-INTERFERENCE



Drawing interference patterns with PGF/TikZ

Version 0.1

9th January 2022

Package author


Keno Wehr

Questions and bug reports

<https://codeberg.org/wehr/pgf-interference>

This \LaTeX package makes it possible to simulate interference patterns occurring on a screen if monochromatic light is diffracted at regular structures of slits. It makes use of the PGF/TikZ graphics package.

The package is still in an experimental stage. The user interface may change in future versions.

 A German version of this manual is available in the file `pgf-interference-de.pdf`.

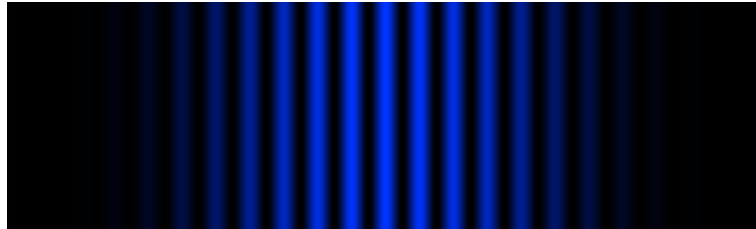
Contents

1	Introduction	2
2	Usage	3
3	Options	4
3.1	Options for the light	4
3.2	Options for the diffraction object	4
3.3	Options for the screen	5
4	Physical theory	7

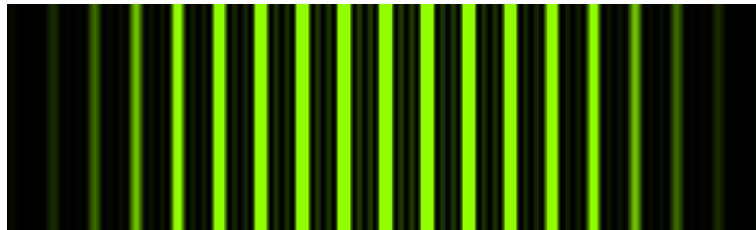
1 Introduction

The occurrence of interference patterns after passing through fine structures of slits gives impressive evidence for the wave nature of light. Such interference patterns are already examined in physics lessons in upper secondary school.

As only a limited stock of light sources and diffraction objects is available in physics collections, it is desirable to be able to present the interference images for wavelengths and slit dimensions that are not experimentally accessible.



Interference pattern for light with a wavelength of 450 nm behind a double slit



Interference pattern for light with a wavelength of 550 nm behind a quadruple slit



Interference pattern for light with a wavelength of 633 nm behind a single slit

The `pgf-interference` package makes this possible. Only monochromatic light and regular slit structures (single, double, and multiple slits) are supported. Also, so far only interference fringes can be displayed, as they occur when the light is expanded vertically, not the typical “interference dots” generated by a laser beam.

The package is subject to the *L^AT_EX Project Public License*, version 1.3 or later.¹

¹<http://www.latex-project.org/lppl.txt>

2 Usage

The package is loaded as usual:

```
\usepackage{pgf-interference}
```

This also loads the TikZ package indirectly.

Compiling documents with many interference patterns can take a long time due to the calculations involved. Therefore, there is a draft mode in which only the screen is drawn, but no interference pattern, which is much faster. The draft mode is activated by the package option `draft`.

```
\usepackage[draft]{pgf-interference}
```

The `pgf-interference` package defines two commands:

`\pgfinterferencepattern{⟨options⟩}`

Generates an interference pattern. The argument is a comma-separated list of options. The available options are described in section 3.

```
\pgfinterferencepattern{slits=3,wavelength=590e-9,slit-distance=3e-5,intensity=2}
```



`\pgfinterferenceoptions{⟨options⟩}`

Sets options without drawing an interference pattern.

```
\pgfinterferenceoptions{slit-width=1e-6,screen-distance=3.5,screen-width=0.15}
```

3 Options

All lengths of the experiment such as the wavelength, the slit distance, the screen width, etc. are to be given in metres, possibly using the scientific notation. For example, a slit distance of 0.1 mm can be typed in as 0.0001 , $0.1e-3$, or $1e-4$.²

3.1 Options for the light

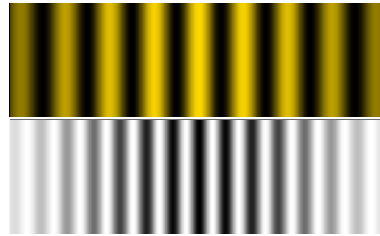
`wavelength = $\langle number \rangle$`

Default: $632.8e-9$

Wavelength of the light in m. The default setting corresponds to the wavelength of the helium-neon laser (632.8 nm). The wavelength does not only influence the position but also the colour of the interference maxima, which is determined with the help of the xcolor package.

For wavelengths outside the visible range, the maxima are shown in black.³ In order to make such maxima visible, the screen colour should be set to white. The longest possible wavelength is 1 m.

```
\pgfinterferencepattern{wavelength=590e-9}
\pgfinterferencepattern{wavelength=350e-9,screen-color=white}
```

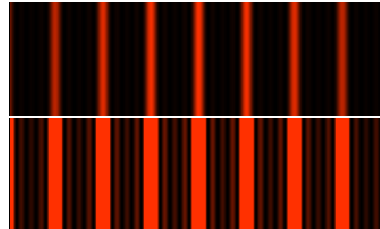


`intensity = $\langle number \rangle$`

Default: 1.0

Relative intensity of the light. If not all expected maxima are visible, the value should be increased.

```
\pgfinterferencepattern{slits=5}
\pgfinterferencepattern{slits=5,
intensity=6.5}
```



3.2 Options for the diffraction object

`slits = $\langle number \rangle$`

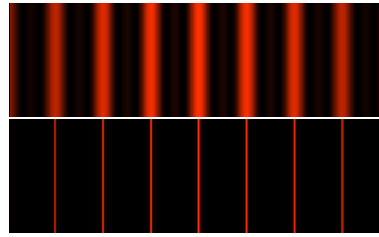
Default: 2

Number of slits

²The lengths are internally treated as floating point numbers of the expl3 module l3fp, whose syntax therefore also applies to the input.

³According to the algorithm of the xcolor package, this is the case for wavelengths below 363 nm and above 814 nm.

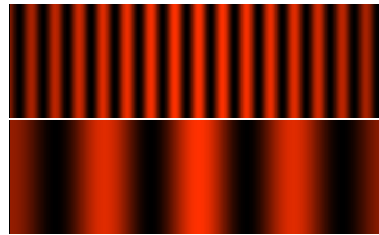
```
\pgfinterferencepattern{slits=3}  
\pgfinterferencepattern{slits=20}
```



`slit-distance = $\langle number \rangle$`
Slit distance in m

Default: 1e-4

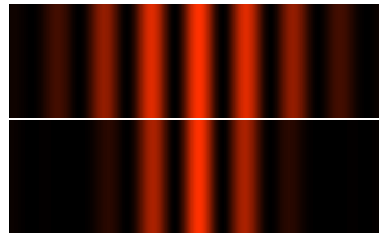
```
\pgfinterferencepattern{slit-distance=2  
e-4}  
\pgfinterferencepattern{slit-distance=5  
e-5}
```



`slit-width = $\langle number \rangle$`
Slit width in m

Default: 1e-5

```
\pgfinterferencepattern{slit-width=2e  
-5}  
\pgfinterferencepattern{slit-width=3.5e  
-5}
```

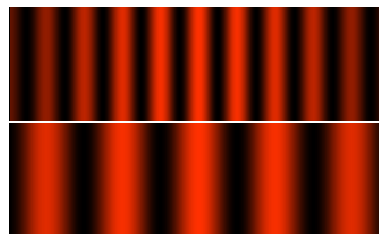


3.3 Options for the screen

`screen-distance = $\langle number \rangle$`
Distance of the screen from the diffraction object in m

Default: 1.0

```
\pgfinterferencepattern{screen-distance  
=0.8}  
\pgfinterferencepattern{screen-distance  
=1.6}
```

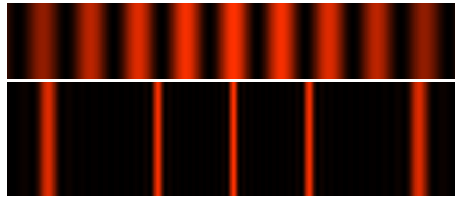


`screen-width = <number>` Default: 0.1
Width of the screen in m

`screen-height = <number>` Default: 0.03
Height of the screen in m

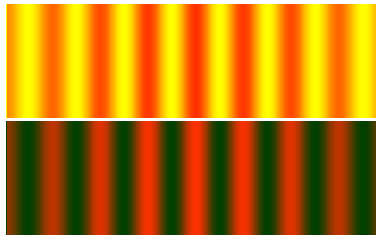
`scale = <number>` Default: 1.0
Factor by which the screen is scaled in the figure
The dimensions for width and height refer to the real screen. The size of the screen in the figure depends on the value of the `scale` option.

```
\pgfinterferencepattern{screen-width  
=0.06,screen-height=0.01}  
\pgfinterferencepattern{slits=10,slit-  
distance=2e-6,slit-width=2e-7,screen-  
width=2,screen-height=0.5,scale=0.03}
```



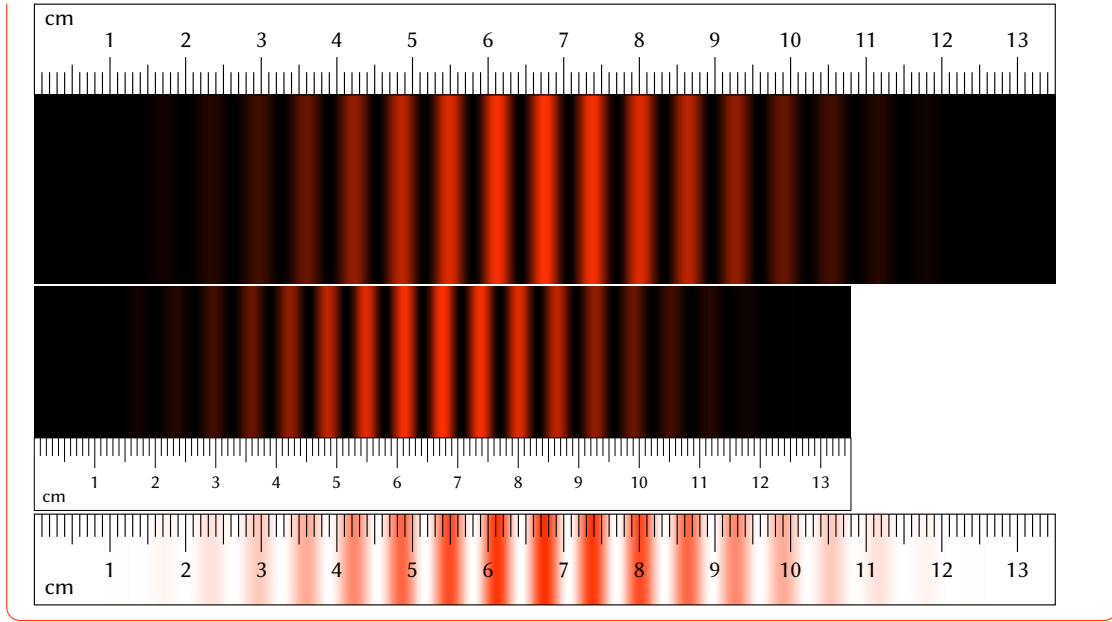
`screen-color = <colour>` Default: black
Colour of the screen. The syntax of the `xcolor` package applies.

```
\pgfinterferencepattern{screen-color=  
yellow}  
\pgfinterferencepattern{screen-color=  
green!25!black}
```



`ruler = above|below|screen|none` Default: none
A ruler with a centimetre scale can be displayed above or below the screen.
With `ruler=screen`, the ruler itself serves as a screen. In this case the `screen-height` and `screen-color` options are ignored.

```
\pgfinterferenceoptions{screen-width=0.135,screen-height=0.025}  
\pgfinterferencepattern{ruler=above}  
\pgfinterferencepattern{ruler=below,scale=0.8}  
\pgfinterferencepattern{ruler=screen}
```



4 Physical theory

The textbooks (e. g. [1], p. 373) give the following formula for the intensity of the light diffracted in the direction of φ behind a multiple slit:

$$I(\varphi) \sim \frac{\sin^2\left(\frac{\pi b}{\lambda} \sin \varphi\right)}{\left(\frac{\pi b}{\lambda} \sin \varphi\right)^2} \cdot \frac{\sin^2\left(\frac{p\pi}{\lambda} s \sin \varphi\right)}{\sin^2\left(\frac{\pi}{\lambda} s \sin \varphi\right)} \quad (1)$$

where b is the slit width, s the slit distance, and p the number of slits.

The first factor describes the intensity distribution as a result of diffraction at the single slit, the second the interference at an ideal multiple slit (see Fig. 1).

To display the interference pattern, we need the intensity as a function of the position x on the screen. From Fig. 2 we get

$$\sin \varphi = \frac{x}{e} = \frac{x}{\sqrt{a^2 + x^2}} \quad (2)$$

where a is the screen distance. Substituting (2) into (1) gives:

$$I(x) \sim \frac{\sin^2\left(\frac{\pi b x}{\lambda \sqrt{a^2 + x^2}}\right)}{\left(\frac{\pi b x}{\lambda \sqrt{a^2 + x^2}}\right)^2} \cdot \frac{\sin^2\left(\frac{p \pi s x}{\lambda \sqrt{a^2 + x^2}}\right)}{\sin^2\left(\frac{\pi s x}{\lambda \sqrt{a^2 + x^2}}\right)}$$

The calculation of the interference patterns is based on this formula.

The reduction of the intensity due to the increasing distance from the diffraction object with increasing x is not taken into account.

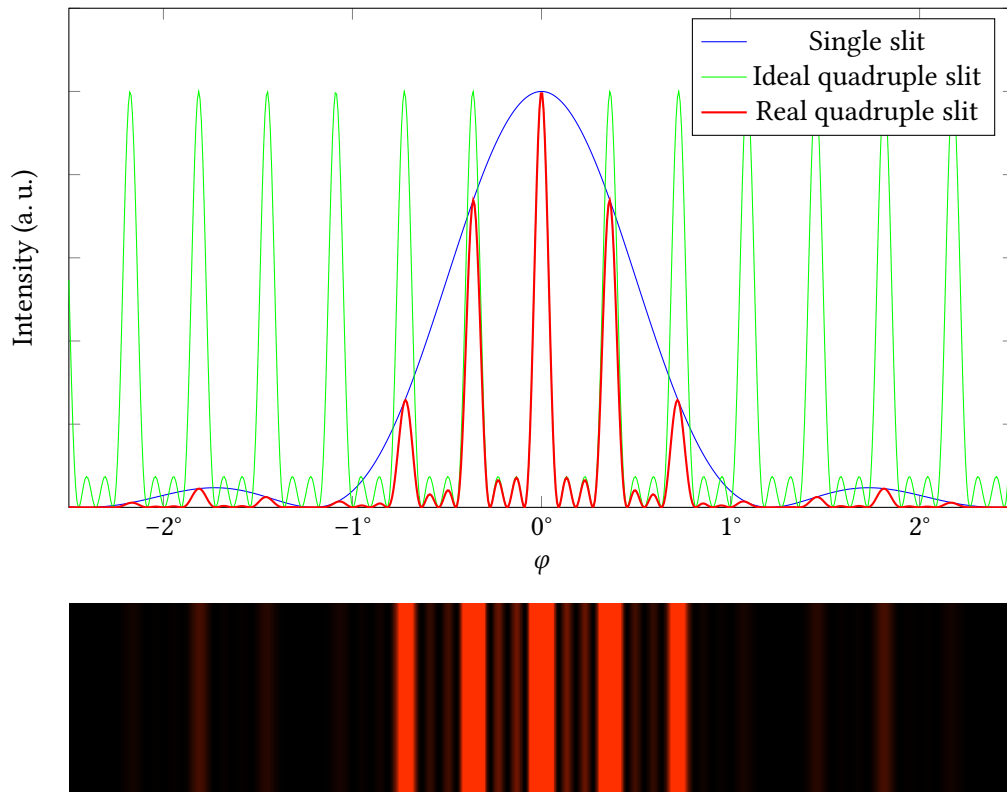


Figure 1: Intensity distribution and interference pattern for a quadruple slit with a slit distance of 0.1 mm and a slit width of 30 μm at a wavelength of 632.8 nm

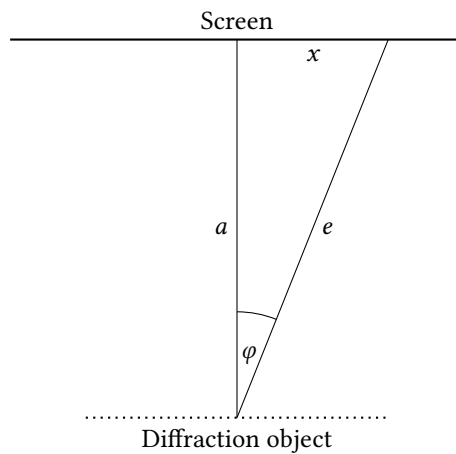


Figure 2: Relationship between the diffraction angle φ and the position x on the screen

References

- [1] Bergmann/Schaefer: Lehrbuch der Experimentalphysik. Band 3: Optik, hrsg. von Heinrich Gobrecht, ⁷1978.