[PICTURE: ©DELPIXEL]

# A simple vision test based on the speckle effect

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**_A non-accommodated, moving eye** with no refractive error perceives a speckle pattern as stationary. If the speckle pattern moves with the motion of the head, the eye is long-sighted (hypermetropic); if it moves contrary to the motion, it is near-sighted (myopic).

**Fig. 1**_A white wall illuminated with coherent laser light appears speckled to an observer (Source: groups.jqi.umd.edu/rolston/research/disordered-neutral-atoms-opticallattices).

**Fig. 2**_Formation of a speckle pattern by superposition of scattered waves in the image plane.

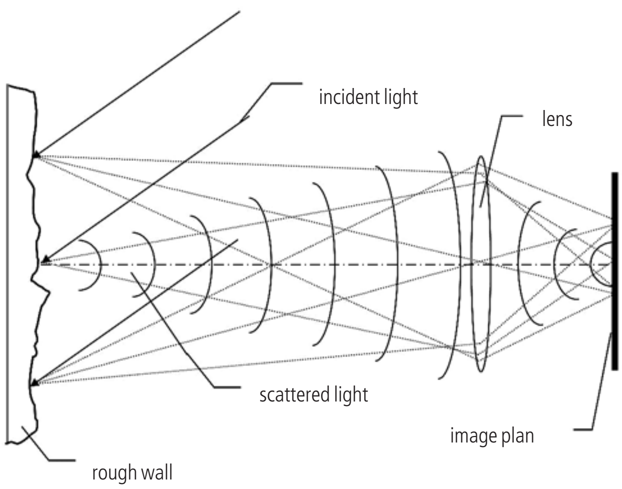


**Fig. 2**

## _Introduction

Let us consider an optically rough white wall. If this wall is illuminated with coherent light (i.e. laser light), interference effects occur. This means that the white wall will appear speckled or spotted to an observer (Fig. 1). This phenomenon is referred to as the speckle effect. Both, dark and bright spots are called speckles. All speckles together form the speckle pattern.

## _Speckle formation

Each point of the wall that is hit by the incident light is a starting point of a spherical scattered wave (Fig. 2). The spherical waves, which are launched from closely adjacent scattering points on the surface, overlap because of diffraction by the lens aperture in the image plane (i.e. the retina of the eye). Because of the roughness of the illuminated surface, statistical phase shifts between the scattered waves occur. Owing to these phase shifts, the speckle pattern results in the image plane.

## _Eye examination

The speckle effect is used in metrology. An example of application is the study of the refractive error of an eye.[2] In this case, the following procedure is utilised. First, the patient looks with one eye (the other is closed) relaxed (i.e. with no accommodation) in the direction of a rough wall illuminated with laser light. The patient perceives a speckle pattern. Then, the patient moves his or her head, for example from bottom to top or from left to right (or vice versa). Finally, the patient perceives one of three variants:

1. The observed speckle pattern remains stationary. This indicates that there is no refractive error of the eye.
2. The speckle pattern moves down (up, right or left) when the head and thus the eye goes up (down, left or right). In summary, the speckle pattern moves contrary to the movement of the head. In this case, the eye is myopic.[3]
3. The speckle pattern moves up (down, left or right) when the head goes up (down, left or right), that is, the speckle pattern moves with the movement of the head. In this case, the eye is hypermetropic.[3]

Figures 3 to 5 illustrate the observed phenomenon. Figure 3 shows schematically a non-accommodated eye with no refractive error in two different positions (down and up). In this case, the eye is referred to as emmetropic. Since the distance between the lens and the retina corresponds to the focal length of the eye, an incident parallel ray is refracted at the same point of the retina regardless of the position (down or up) of the eye.

Figure 4 shows a myopic eye, that is, the eye is too long. In the two positions of the eye (down and up), an incident ray is refracted at two different points of the retina. Since the brain exchanges bottom and top, the perceived speckle pattern moves opposite to the motion of the eye.

Figure 5 shows a hypermetropic eye, that is, the eye is too short. In this case, the situation is reversed compared with Figure 4.

## _Conclusion

A speckle pattern is perceived as stationary if a non-accommodated and non-defective eye is moved. If the speckle pattern migrates opposite to or with the movement of the eye, it is myopic or hypermetropic, respectively. You can convince yourself of the described effect by observing, for example, a white wall illuminated with an expanded laser beam. By wearing different goggles (with different focal lengths), you can simulate emmetropia, myopia and hypermetropia._

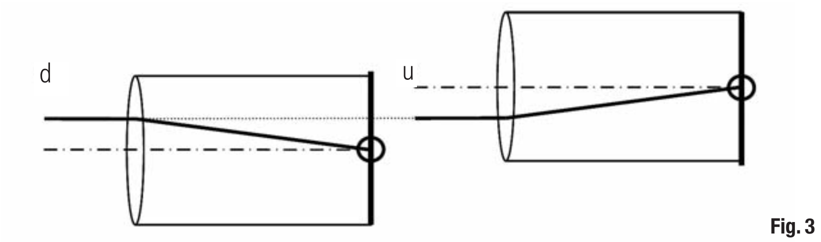


Fig. 3

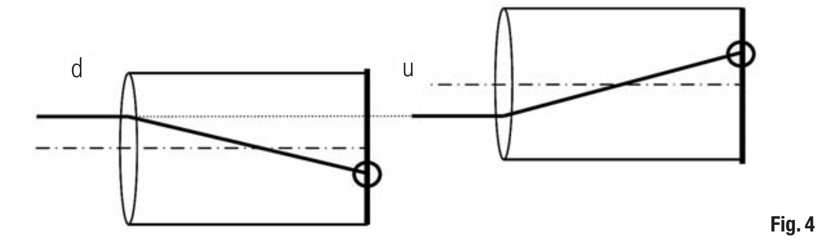


Fig. 4

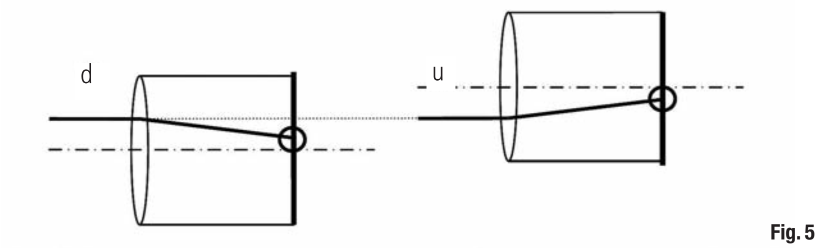


Fig. 5

*Sources:*
*http://elib.uni-stuttgart.de/opus/volltexte/2011/6175/pdf/tiz122.pdf; (Download April 29, 2015)*
*http://groups.jqi.umd.edu/rolston/research/disordered-neutral-atoms-optical-lattices; (Download September 23, 2015)*

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**Fig. 3**_An optical ray parallel to the optical axis of the lens is always refracted at the same point of the retina.

**Fig. 4**_An optical ray parallel to the optical axis of a myopic eye is refracted at two different regions of the retina; the point of impact of the ray on the retina moves parallel to the movement of the eye.

**Fig. 5**_An optical ray parallel to the optical axis of a hypermetropic eye is refracted at two different regions of the retina; the point of impact of the ray on the retina moves antiparallel to the movement of the eye.

### Kurz & bündig

Betrachtet man eine optisch raue Wand mit kohärentem Licht (Laserlicht), so treten Interferenzeffekte auf. Es lassen sich helle und dunkle Flecken – ein sogenanntes Speckle-Muster – beobachten.

Der Speckle-Effekt lässt sich messtechnisch ausnutzen, beispielsweise in der Ophthalmologie. Ein Speckle-Muster wird bei bewegtem, nicht-fehlsichtigem Auge als stationär wahrgenommen. Wandert das Speckle-Muster mit der Bewegung des Kopfes mit, ist das Auge übersichtig. Im anderen Fall ist es kurzsichtig.

Durch das Tragen verschiedener Brillen (mit verschiedenen Brennweiten) können zudem Emmetropie, Myopie und Hypermetropie simuliert werden.