

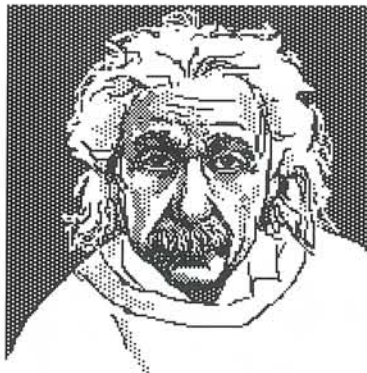
## Welcome!

We are very pleased to welcome you to our new newsletter. Previously we have issued a newsletter at irregular intervals, but are now making a more concentrated effort. We have chosen to call it Non-Contact, referring to the applications that our components are used in, non-contact measuring systems, and our intention that Non-Contact will keep us in contact with our customers and all others that are interested in SiTek, our products and how they are used.

The contents will be a mixture of information on our products, information on applications, a PSD school (see the right column) and similar topics, as well as lighter, non-technical articles. We hope that you will find something interesting and worth reading in every issue. Our goal is to issue at least three newsletters every year. This year we plan to issue four numbers in English.

We hope that you will continue to follow our activities, as we believe an exciting future awaits, which we hope to explore together. If you have any material that you think would be suitable for Non-Contact, or if you have an opinion regarding the newsletter or our products that you would like to express, we urge you to contact us. We cannot improve without your feedback!

If you have a colleague or a friend that you believe might be interested in Non-Contact, send us his or her name and address so that we can send an issue to them. You will find our address and telephone and fax numbers at the bottom of the last page.



"Imagination is more important than knowledge"

Albert Einstein

## PSD school

The PSD school will be an important and recurring item in our newsletter. About half of every number will be devoted to it. The purpose is to spread information and knowledge of how measuring or inspection equipment can be constructed incorporating PSD technology. All those who already have done this know that, besides knowledge of PSD, it requires familiarity with optics, electronics, light sources, mechanics and also computer technology and programming. It is our goal to cover all of these areas, not in great detail, as that would require several textbooks, but in enough detail that most difficult aspects are discussed.

We will be getting assistance from some of the real experts in these areas. If you have an application, an idea or a measurement problem, you should be able to get enough help that you yourself can construct the first prototype. Besides the PSD school we will be presenting many different applications and measurement problems where PSD technology has been proven to function well. We hope and believe that this will be a source of inspiration. And together with the PSD school, your ideas can become reality!

We welcome responses to these articles. Are the discussions at the right level, are they too easy or too difficult, is important information missing, or are we too explicit? We request your help to make these articles a useful tool.

The first article is an introduction to the subject of optronics and why we need position sensing detectors, written by Mr. Lars Stenberg, ESDE AB. In the next number Mr. Stenberg is going to discuss optics and how to arrange the various parts, in relation to each other and to the measured object.

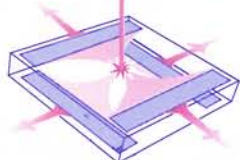
**Who said what?** Enter SiTek's contest. You probably recognise most of these four quotations, but who said them? Send your answers to us on a postcard, in a letter or by fax. We will give prizes to everyone that has all four right. The correct answer will

1. All people complain about their poor memory, but nobody about their intelligence.  
1. François de la Rochefoucault  
X. Blaise Pascal  
2. Jean de la Fontaine

2. The clumsy smith blames the iron.  
1. Socrates  
X. Dante Alighieri  
2. Plato

3. Better to light even a tiny light than curse the darkness.  
1. Descartes  
X. Quintus Horatius Flaccus  
2. Confucius

4. The wise wish to know, the foolish to speak.  
1. The Koran  
X. The Bible  
2. The Talmud



# A story that began long ago

by Prof. Torkel Wallmark

The Position Sensing Detector (PSD), which senses the position of a light spot on its surface and can use this to determine the direction of a source of light was discovered as early as 1957:

J T Wallmark, "A new semiconductor photocell using lateral photoeffect", Proc. I.R.E., vol. 45, 1957, s. 474-483.

The background to the discovery was our attempts to understand and influence the surfaces of the germanium transistors of that time. During our work, which studied the influence of thin surface layers, we found that a photoelectric voltage appeared not only perpendicular to the surface, but also laterally along the surface, an effect unknown until then. The lateral voltage was measured with two electrodes on the surface, and the voltage sank to zero when the normal to the surface pointed in the direction of the light source. The registration of voltage was extremely sensitive and it was noted with great interest that merely taking some steps across the floor, which rested on steel beams, caused enough of a vibration to be immediately registered by a photocell that stood on a laboratory table on the same floor.

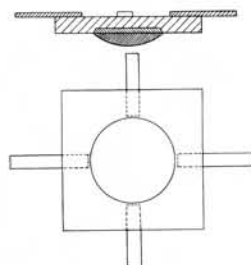
The discovery was also noted in Sweden, and Mr. Lindholm at the institution for applied electronics, who was working on the prelim of measuring movements with a non-contacting method, needed such a photocell. Mr. Morander, who at that time, in 1970, had started Selcom AB started working with commercialisation of Mr. Lindholm's idea. One difficulty was that the photocell was not linear, it did not give the same signals for all x and y co-ordinates on the surface. Together with Mr. Petersson, who had expertise in the area of manufacturing technology, a research activity stretching across several years was started in which Mr. Lindholm and Mr. Petersson together improved the properties of the photocell. This work resulted in a new patented method which immediately made the system applicable to many difficult measurement problems and formed the basis of a number of new products. As a result of this, they started SiTek Lab AB in 1976 for the manufacture and sale of position sensing photodetectors.

The story is a textbook example of how basic research gives rise to a new effect and leads to practical products, which in turn need further research in order to refine properties demanded for practical applications for. It is also a good example of the role of the university in generating such research as well as following up research with practical application by the starting of small companies.

Prof. Torkel Wallmark worked 1953-1964 at RCA Laboratories in Princeton where he invented the PSD, among many other inventions. During 1964-1983 Wallmark was a professor at the institute for solid-state electronics, CTH, where the continued development of PSD's took place. Wallmark has been a professor at the department for innovation technology, CTH, since 1983, and is currently retired.



Torkel Wallmark investigating position sensing with his first photocell in 1956.



This is Figure 8 from Wallmark's 1957 article, showing a two-dimensional lateral photocell (compare with a present-day PSD, Figure 2, page 3).

## PSD with built-in stray light elimination

Does stray light affect your measurement results or maybe even make measurements impossible in your distance measurement probe?

A serious problem in certain applications is the existence of stray light with the same wavelength and modulation as the light being measured. Stray light can come from internal reflections in the measuring probe, from secondary reflections from the measured object or from light dispersion due to smoke, dust particles etc. that may exist between the measured object and the measuring probe. This problem is one of the most serious disadvantages when using Position Sensing Detectors (PSD). In many cases, this problem is the only disadvantage. A displacement of the light's "centre of gravity" occurs, and with that a positional error in the component and a measurement error in the system. Furthermore, if the stray light spreads out over a large area, speed and linearity may be affected. This has been a serious enough problem that users have been forced to find other solutions

Now SiTek is introducing the next generation of PSD with built-in stray light elimination. This is a recently patented solution that eliminates most problems with stray light. All problems with decreased speed and linearity are now completely eliminated as well as, in most cases, the problem with displacement of the centre of gravity. This means that now you can gain the full benefits of PSD - high sampling frequency and high resolution - in applications where the existence of stray light has forced you to find other solutions.

The new technology is most suitable for applications where one-dimensional PSD is used. To start with, SiTek will offer one-dimensional PSD with active lengths of 5 and 10 mm. It will also be possible, as before, to manufacture custom-made components with the new technology.

These components have the same high performance with respect to linearity, leakage current, noise etc. as our standard components, which are ranked as the best by PSD users around the world. It is possible to use the same electronics as before. The only external difference is that these detectors have a contact to ground, besides the usual contact to bias and two contacts to the front side (X1 and X2). In other words there are four contacts instead of three; it is only necessary to connect the fourth contact to ground.



# SiTek's PSD School

## Section 1 by Lars Stenberg, ESDE AB

### What is meant by optronics and why is the existence of position sensing detectors so important?

1971 is the year that optronics was born.

By optronics we mean an area of technology that are based on the simultaneous use of optics and electronics. Since optical elements such as lenses and prisms must always be fixed with the help of mechanical parts, often with a high degree of precision, optical instruments generally consist of precision-tooled parts. Optical instruments also often contain a computer. If we wish to develop, construct and manufacture optical instruments, we need knowledge of optics, electronics and precision tooling, and often knowledge of computer technology and programming.

In order to translate light into electrical signals, light-sensitive detectors that produce an electrical signal when exposed to light are needed. Up until the beginning of the 1970's, light-sensitive detectors were either bolometers, selenium cells, photocells, otomultipliers or photodiodes. However, in 1971 the so-called CCD array was invented at AT&T Bell Telephone Lab in the USA, and at about the same time the so-called PSD detector was invented by Chalmers engineers L.E. Lindholm and G. Petterson. The interesting thing about these detectors was that they were able to sense position, but we will return to that subject. The first microcomputer, the Intel 4004, was also constructed in 1971. As we will see further on, these inventions were important in themselves, but together they were so important for the possibility of constructing optronics products that if one wishes to determine a birth date for optronics, I know no better year than 1971.

### Why are position sensing detectors so important?

Let me give you an example of a simple measuring device which is used in the entire industrialised world in a number of different applications for automatic measurement and production control. We start by looking at Figure 1 to the right. A is a source of light that sends out a small beam B, which strikes surface C at point D. If surface C is not a mirror, the light will be subject to diffusion by reflection, that is, the light will be reflected in all directions in a hemisphere around point D. The intensity will vary somewhat in different directions depending on the properties of surface C. If we place a lens or an objective E such that the lenses optical axis intersects surface C at point D, all light passing

through lens E will be more or less well focused (depending on what kind of lens is used) at point F. The distance EF depends on the distance DE and the lens's focal length.

If surface C is moved up to a new position C', light ray B will instead be diffusely reflected around point D'. Since lens E remains in its original position, the reflected light will now be focused somewhere along the extension of the line D'E. Using the so-called lens formula, that point can be calculated precisely<sup>1</sup>. In the figure the new position of the image is denoted with F.

If the surface C is instead moved down to the new position C'', by the same argument as above there will be a new image point F''<sup>2</sup>. The alert reader will realise that when the surface is moved from C' to C'', the reflected and focused light's image point will move from F' to F''.

In order to measure the movement of surface C by using the movement of image point F, one must have a position sensing detector that can be placed along the line F'F''. This meant that before 1971 it was impossible to manufacture measuring instruments based on the so-called triangulation principle. As will be seen in the coming articles, for the same reason it is impossible to manufacture other kinds of measuring devices without access to position sensing detectors. These detectors are therefore necessary if optronical measurement and control devices are to be constructed.

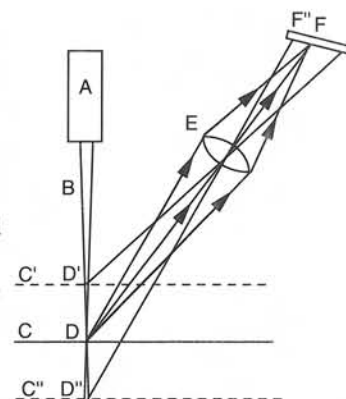


Figure 1.  
Principle of a triangulation probe.

### The functional principle of a PSD

Now we look a little more closely at how position sensing detectors are function without, however, going into detail<sup>3</sup>. PSD is an abbreviation for Position Sensing Detector.

A PSD is essentially a photodiode that transforms light striking it to an electrical current. The component has two contacts placed directly across from each other on the active surface, see the Figure. For a two-dimensional PSD we also have a pair of electrodes placed on the back side such that they are at a 90° angle to the electrode pair on the front. The current that is generated will be divided between the two contacts on each side (in one case because of electrons and in the other case because of holes). The active surface functions as a very homogenous resistance, so that the current in each contact depends linearly on where on the surface the light strikes, that is, the distance to each contact. The position in the y direction is obtained through the simple formula  $(Y1-Y2)/(Y1+Y2)$ , where Y1 and Y2 are the currents from each contact. The position is obtained similarly for the x direction. In other words, we can

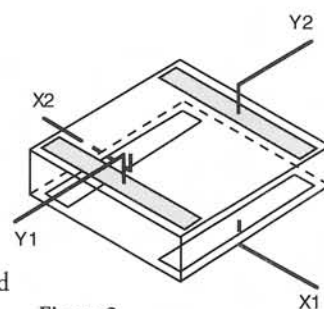


Figure 2.  
Structure of a Sitek two-dimensional PSD.

1. Future articles will describe in more detail the advantages and disadvantages of different kinds of components and various optical phenomena.
2. The reason that the line F'F'' forms an angle with lens E's optical axis will be dealt with in a coming article.
3. Readers wishing further information are referred to SiTek's manuals and to later articles.

determine the light's position in both x and y directions.

The principle above can also be used for constructing linear PSD detectors. In that case it is sufficient with one electrode on the silicon chips back side. It is even possible to make an almost circular PSD detector from a linear one

by making the active upper surface in the form of an almost closed circle.

#### The functional principle of a CCD

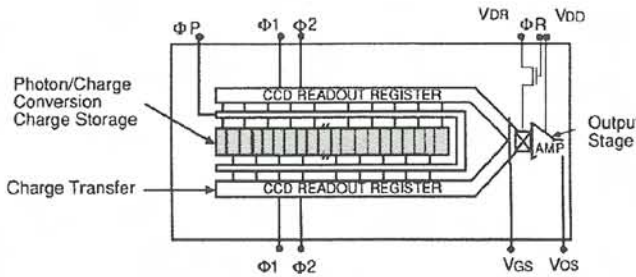


Figure 3.  
Block diagram of a linear CCD.



Lars Stenberg has worked with optical devices and electro-optical measuring systems since his graduation from Gothenburg University in 1967. He worked first at AGA and, since 1976, at Elopicon AB, a company based in Skellefteå which he started together with five partners. In 1992 Lars formed his company Electro-Optical Systems Design and Education AB and since 1989 he has also worked in NUTEK's technical and scientific board.

CCD stands for Charge Coupled Device. In order to understand how a CCD functions, we start by studying one-dimensional or linear CCD detectors, which have their light-sensitive elements or photodiodes arranged in a line as shown in Figure 3 above<sup>4</sup>. When the different photodiodes are struck by light, the light is transformed into electrical charges whose size is proportional to the intensity of light.

The generated charges are stored in an MOS capacitor, which is connected to each light-sensitive element. When the CCD array's light information is to be registered, the different charges are moved along the row of capacitors, just as in an analogue written register.

When the charges are moved at the time of registration, they are transformed to a voltage that is directly proportional to the size of the charges, and thereby proportional to the intensity of light striking the detector.

A CCD array can, in other words, be considered a "black box" that transformed a spatially distributed light to a signal voltage distributed in time.

#### Comparison between a PSD and a CCD<sup>5</sup>

If we now compare a PSD and a CCD, there are a number of differences that can be quite important to be aware of when choosing a type of detector for a certain application.

If we begin by looking at the resolution, it is possible to measure changes in position with a PSD as small as several nm (1:1 000 000), but

for common applications a resolution of 1/2 000-1/4 000 of a PSD's linear extent are often used. A PSD with a photosensitive surface of 4 x 4 mm has then a resolution of 1-2  $\mu\text{m}$ . A CCD, however, has a pixel size of 7 x 7  $\mu\text{m}$ , and thus a resolution of 7  $\mu\text{m}$ , since every photosensitive element is only separated from its neighbour by an extremely thin oxide layer. By recording the amount of light striking every pixel and calculating the intensity curve purely mathematically, the centre of the so-called "centre of gravity" for the light can be calculated in some cases. The resolution of a CCD can in such cases be increased to 0,5  $\mu\text{m}$ .

The sampling frequency may be 10 Mhz to 10 kHz for a PSD, depending on the size, as compared with 2 kHz for a linear CCD and 30 Hz for a CCD matrix<sup>6</sup>. The high sampling frequency achieved with a PSD is one of its key advantages.

If a PSD is struck by stray light with the same wavelength and signal frequency as the measurement ray itself, it will be difficult to deal with, since the x-y co-ordinates that the PSD presents depend on the common "centre of gravity" for the measurement ray and the stray light. As for the CCD array, it is possible to set a threshold level that serves to filter out signals weaker than the set level. In this way the error introduced by the stray light can be eliminated, given that the signal voltages caused by the stray light are less than those caused by the measurement ray.

And finally, looking at the cost of using a PSD or a CCD, it is possible to construct cheaper measuring systems using small PSD detectors than with either linear or matrix types of CCD.

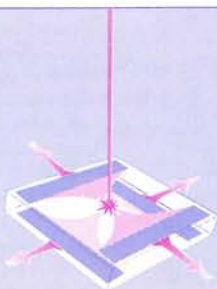
#### What can a PSD be used for? Examples of applications.

In a series of coming articles we will discuss various applications in which position sensing detectors can be used. The next article will therefore discuss the choice of components and geometry that must be made when constructing a triangulation probe.

4. The figure is reproduced with permission of Thomson Components AB.

5. This will be expanded on in a later article.

6. There is a special variant of linear CCD that is registered in parallel and therefore allows greater speeds.



Distributed by

SiTek Electro Optics AB, Ögärdesvägen 13A,  
S-433 30 Partille, Sweden.

Tel: +46-31-44 06 70. Fax: +46-31-44 14 40.

**SiTek®**  
**ELECTRO OPTICS**