



NDF is an innovative company that produces custom-specified Cold Cathode Fluorescent Lamps for high-end LCD backlight applications in niche markets. Its products are used in air- and spacecraft, air traffic control, medical and military systems, and in emergency lighting, as well as at the top level of decorative applications, such as points of sale, retail and shop lighting. In the past 17 years, the company continued to 'make light' and innovate in both display technology and decorative lighting, which has resulted in several customized solutions for customers.

Making Light

When in the mid-1990s Philips demanded that new products had to show a return on investment within one and a half years, this proved unfeasible for the Cold Cathode Fluorescent Lamp (CCFL). As a result two managers, Gerrit van Amelsvoort and Coen van 't Westeinde, suggested a management buyout of this product line.

These entrepreneurs were driven by a belief that there was a niche market for this product. They believed their end products could be an essential part of backlit LCD screens.

NDF Special Light Products was thus founded in May 1999 by a management buyout. Using unique lamp making equipment, Gerrit van Amelsvoort and Coen van 't Westeinde started to produce, custom-specified Cold Cathode Fluorescent Lamps for high-end LCD backlight applications. The company's production plant and sales office are located

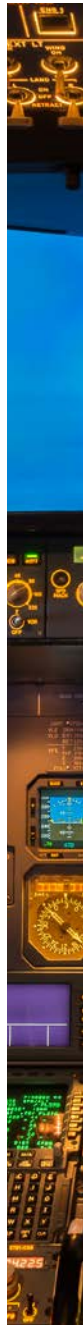
in Roosendaal in The Netherlands, from where NDF distributes its products both to the home and foreign markets.

The buyout enabled a continued development of the lamps for more contrast and enhanced colour. Philips retained the patents, but NDF obtained a licence which enabled them to continue research and development of the lamps. This lamp concept, which is still unique in its performance and which is covered by no less than ten patents, has proven to be a perfect solution for those applications where reliability and extreme performance are required.

NDF sells its products to customers worldwide and it is known for its high quality standards.

Aerospace, medical and military markets

Today NDF still has its focus on the high-end LCD markets, more specifically those of aerospace, medical and military. In addition, the technique is also of interest for the consumer market: for example the product is easy to implement into decorations. The success of NDF is exemplified by the fact that the company is world leader in backlighting for mammography (92% market share), air traffic control (83% market share) and cockpit display units. However it remains a challenge to find a good balance between short and long-term activities. One reason for this is that the requirements for the high-end market are extremely demanding and a significant amount of time is put into the manufacturers' test programmes. This creates a long period of uncertainty when waiting to see if the NDF technology will be chosen. On the other hand,





there is a market advantage for NDF because, if its products are chosen, manufacturers tend to remain loyal and buying is guaranteed for a long time.

During the last decade NDF has quickly developed world leadership in its market sector. This strong position is possible because the NDF technology has a number of unique selling points: firstly, the lamps have a very long life (three to five times longer than comparable products), secondly, they are extremely robust (shock and vibration-proof, important in aircraft or spacecraft and in military applications) and, thirdly, they show a more highly accurate and stable colour (little variation is of importance for the assessment of breast images). Additionally NDF makes the product itself and therefore has maximum knowledge of the entire process, from development to after-sales. This makes it possible to react quickly to customer demands and market developments. NDF's company history also makes a difference: clients consider NDF to be reliable with a superior product, a reputation enhanced by the company's close relationship with Philips.

Aerospace applications

Because of their unique characteristics, NDF products are used in all areas of the aerospace industry, from jetfighters to helicopters, large commercial aircraft and even in the International Space Station. Here reliability and proven quality are fundamental requirements, because failures can have major consequences.

An excellent example is the use of backlights in modern cockpit displays that are based on light-emitting diode (LED) technology, using white LEDs or triple-colour LEDs. As cockpit technology has been characterized by a rapidly ageing and complex control system, NDF has joined other companies in the DERPHOSA (Technology Development of Remote Phosphor for Avionic Cockpit Displays) consortium, in order to develop a new backlight concept, offering a simpler solution with a more stable colour yield and a much higher efficiency. The new backlight system is based on colour conversion by remote phosphor called ARPHOS®. In addition to LED lighting as a light source, the new type of display makes use of a phosphor

plate, which converts blue LED light into white light. In 2014 the new technology passed validation testing, at a 10-km altitude in extremely bright sunlight, scoring very well and clearly offering better contrast and greater clarity than current displays.

"For over two years we took part in the DERPHOSA project and joined forces with NLR (Netherlands Aerospace Centre) and several partners to work on a new technology for cockpit displays."

Another application offered to this market by NDF is for the flight simulators used during pilot training. These devices are used continuously and demand the highest reliability. NDF understands the specific requirements for this demanding environment by the experience it has gained as a supplier in the avionics market. NDF's simulator displays will have the realistic look which is expected by the pilots during their training.

NDF offers customized display solutions adapted to the specific needs of the pilot training market. These displays also contain



the Advanced Remote Phosphor technology called ARPHOS® developed by NDF for use in the high-end display market. The adoption of this technology for such a market has been undertaken in collaboration with the Netherlands Aerospace Centre and a leading European display builder. ARPHOS® has the notable advantage that the colour of the display can be adjusted to match the original display without losing any performance during its lifetime as well as high energy efficiency and low energy consumption.

"In 2011 we expanded our backlight range with a new patented technology; ARPHOS®. It is an LED technology in combination with remote phosphor, offering the highest reliability." - Coen van 't Westeinde, CEO

Not by backlight alone

NDF produces a number of products for the high end of the professional light market with its Long-Life Lightline and Shelfline products as excellent alternatives to LED lamps. The many options these products offer to integrate or mount the slim modules, give lighting designers and architects numerous possibilities to create the perfect atmosphere. The modules combine the advantages of LED i.e. long lifetime, low energy consumption and slim size, with those of low power, less heat, full length illumination without 'dots' and various colour temperatures. The lamps can be used in retail units, shop lighting, kitchens, points of sale, architectural detailing, guidance systems, signage and many other areas.



In 2014 NDF introduced another innovative product: the Caret Squirrel Cage lamp. This is the perfect energy saving successor to the traditional bulb lamp (the Edison Squirrel Cage lamp). The Caret combines a warm colour and beautifully sophisticated design with low energy consumption, long lifetime, easy dimming and high switching reliability. It gives a cosy atmosphere and stylish ambience, just the things traditional LED lamps cannot offer.

New challenges: from threat to opportunity

Ten years after starting the company, NDF was faced with a new challenge as LED (Light Emitting Diode) lights flooded consumer markets and began to replace the CCFL's of the LCD backlight. NDF customers followed these consumer market fluctuations with interest and it was not long before the company was encouraged to investigate whether backlit LED could provide the same quality screens.

This emerging demand prompted NDF to organize a survey among its direct customers in several markets, for example manufacturers of air traffic control equipment, as well as end users, for example the air traffic controllers themselves, about their short, medium and long term vision. These enquiries resulted in the identification of up to fourteen technologies that might meet the needs of customers and end users, but Remote Phosphor was eventually chosen as the technology to build on.

Choosing Remote Phosphor (ARPHOS®) was a major strategic decision for the company. NDF moved up the value chain and entered a new market with great potential. Meanwhile, ARPHOS® as technology is now widely used in the market, both in air traffic control centres and in avionics. NDF provides the lighting for cockpit displays and, in the growing market for mammography, grey scale displays are changing to colour displays developed by NDF.

Strategic Evolution; Quantum Dots

The introduction of ARPHOS® can be seen as an adequate response to market developments. But in the eyes of NDF it is basically a passive strategy, imposed by the outside world.

In order to keep momentum and to build its own future, NDF has drawn up a roadmap that should lead to a new innovative product: Quantum Dot technology. This technology gives a wider colour gamut with even better colour saturation, is more energy efficient and, unlike some Quantum Dots, free of Cadmium. In the near future NDF will introduce this innovation into the portfolio as it is a robust technology especially suitable for the high-end market such as avionics and air traffic control. Because of the colour characteristics, Quantum Dot technology is also of particular interest to the medical sector, especially endoscopy and pathology. This strategic approach also reflects the ambitions of NDF.

"We want to grow further in aviation, air traffic control and the medical sector. As a next step we want to develop the overall display of the flight simulators for Airbus and Boeing, with the overall display of aircraft as the ultimate goal."

THE LIGHT EMITTING DIODE

An LED is a solid state light emitting diode. The first commercial LEDs, introduced in 1962, emitted infrared light. An LED emits only a single wavelength of light (colour) and the first visible wavelength LED's were red, followed by orange and yellow, and then green. This single colour is well suited for such uses as an indicator lamp or an alarm clock display, but of no use if used to create any kind of light source with a wide colour spectrum. The final piece of the puzzle was the blue LED and with its invention, the white LED became possible.

ARPHOS®
The white LED is created by using a fluorescent chemical in the bulb, which converts the blue light into white light. The LED is coated by a phosphor material that shift the wavelength of some of the blue light to green, yellow and red. The Remote Phosphor technology effectively separates this phosphor coating from the LED itself, allowing different phosphors to be interchanged in a light housing. The result is a clear white light with very stable characteristics over time as the phosphors are not subject to heat degradation as they are separated from the LEDs.



QUANTUM DOTS (QD'S)

QD's are very small particles, so small that their optical and electronic properties differ from those of larger particles. Because of their highly tuneable properties, QDs are of wide interest.

The ability of QDs to precisely convert and tune a spectrum makes them attractive for LCD displays. Previous LCD displays would waste energy converting red-green poor, blue-yellow rich white light into a more balanced lighting. By using QDs, only the necessary colours for ideal images are contained in the screen. The result is a screen that shows more accurate colours, is brighter, clearer, and more energy-efficient.

