ARTIFICIAL NANOSTRUCTURE MATERIALS FOR OPTICAL POWER CONTROL DEVICES

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ABSTRACT

Nowadays cameras are integrated in many optical systems. Regulation and control of optical power in cameras presently requires an electronic feedback control or offline data processing, which introduces complex and expensive systems. We present a non-linear, solid-state passive Dynamic Sunlight Filter (DSF) performing this process, yielding similar results - passively. When sunlight intensity increases, the DSF transmission decreases according to the amount of the incident lights, resulting in a darkened state, which is limited only to the over exposed area. The area returns to transparency once the amount of light decreases below a threshold level. We demonstrate here new experimental results showing an increase in the camera's dynamic range when using the DSF.

Keywords: Anti-blooming, Sunlight filter, Camera, light Regulation.

1 INTRODUCTION

Nowadays cameras are integrated in many optical systems. Since the direction of viewing is not always known and can be in certain cases in toward the sun, events of camera blinding are very likely to occur. Regulating optical power levels within cameras [1] requires today an electronic feedback control or offline data processing, which introduces complex and expensive systems. When regulation of light power fails, blooming effect is created. When light passes the lens of a digital camera and is captured by the CCD sensor it is converted into an electrical charge. There is a limit to how much charge each pixel or photosite can store. Excessive charge in a photosite will overflow to its neighboring pixels causing an effect, which is called blooming. Manufacturers try to eliminate this effect by "anti-blooming gates" which can be compared to vertical drainage channels running beside each row of photosites [2]. These allow the overflowing charge to flow away without affecting surrounding pixels [3, 4]. Though these anti-blooming gates are fairly successful at avoiding the problem, there are exposure situations where blooming can still occurs. Sometimes the blooming is such that data is lost and cannot be recovered by any sophisticated software.
The need for a better light control was the trigger for our effort in developing a family of products that are able to control and regulate light, in a passive way, all based on our already proven principles of Optical Power Control (OPC) [5, 6] using nanotechnology and nonlinear nanostructure optics. Most of our OPC past applications were controlling laser optical power for various optical systems and applications. We developed the Dynamic Attenuator for the Telecom [7] market, a device for limiting and regulating the optical power propagating in an optical telecom network. In this area we have also developed the Optical Fuse [8] that protects the optical network from over power and optical spikes. Based on similar nanotechnology we developed the Wideband Protection Filter (WPF) [9, 10], which is designed to protect sensors as well as the human eye, from high power lasers impinging into optical systems, such as sights, binoculars, cameras etc.
In this paper we report on the Dynamic Sunlight Filter (DSF) [11, 12], which is a passive solution dedicated to protect against sunlight overpower, controlling and regulating applications. In the normal state, when incident light is below a predefined level the DSF is highly transparent, light just passes through it. As the light level is increased and gets more intense, such as in the case of morning sun, or the headlights of an approaching car facing the rear-view mirror, the DSF transmission decreases accordingly, eventually reaching a darkened state. The darkening effect is selective and is limited only to the intense light areas in the image. This process is reversible and the filter recovers its transparent state once the intensity of light decreases to its normal level.
We demonstrate our DSF functioning when introduced as an add-on module to a camera, and when integrated near the sensor itself. We present new experimental results including attenuation values, time response and imaging improvement as function of DSF type.

2 DSF – REQUIREMENTS

The DSF [11, 12], is a passive solution dedicated for sunlight controlling and regulating applications, and is based on the limiting mechanism. The limiting function implies that in the normal state, when incident light is below a predefined level the DSF is highly transparent, light just passes through it. As the light level is increased and gets more intense, such as in the case of direct sun impingement or morning sun, the DSF transmission decreases accordingly, eventually reaching a darkened state. The darkening effect is selective and is limited only to the intense light areas in the image. This process is reversible and the filter returns to its transparent state once the intensity of light decreases to its normal level.

One of the DSF immediate applications, which is presented and discussed in this paper, is increasing the dynamic range of cameras. The major effect of the DSF is reducing the saturation and blooming phenomena, and by doing that allowing picture taking in an intense high power environment, such as toward the sun [12]. The DSF is placed at a focal plane of the imaging system, either on the sensor itself, or at a focus of an external add-on module e.g. a 1 to 1 magnification telescope, having a cross over. The light reaching the DSF will be limited only if its intensity is above a predominated threshold. The light below threshold intensity will pass the filter with no significant change. The overall result is that the blooming effect is prevented and we get a net image with better contrast, details, and clarity.

2.1 DSF integration inside a camera

The DSF is placed at the focal plane of the optical system, and in our case, of the camera. There are two main places for a filter at the focus: 1. Directly on the sensor itself, or at small or minimal distance from the sensor (Figure 1); 2. As an external add-on module (Figure 2).

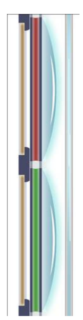

Figure 1: Integration of DSF on the camera's sensor directly

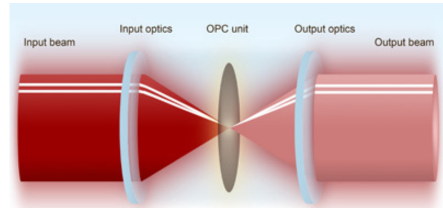

Figure 2: Integration of DSF within an external add-on module 1X1 to be added in front of a camera

2.2 DSF preliminary specifications

Our design goal for a DSF filter integrated inside the camera is described in Table 1. The linear transmission refers to the transmission of the filter when not activated. In activated mode, hence – high optical power, we define the filter maximal attenuation to be more than 30dB. In general, the attenuation is input power dependent, i.e. the higher the input optical power is the larger blooming effect we get, resulting in larger attenuation level, preventing blooming. The practical meaning of this effect is that when integrating this DSF within a given camera, the dynamic range of the camera increases by 30dB. In scenarios where the camera enters saturation, adding a DSF will increase its saturation value by 30dB.

For certain applications, the design goal for DSF is wide operation wavelengths from the 400nm and up to the 1700nm. However, the DSF experimental results we present in this paper are mostly for the visible range.

The DSF rise time is defined by the activation time of the DSF: the time to transfer the DSF from 80% transmission to operational attenuation (30dB at most). The recovery time is divided into two regimes: the first one is defined as the recovery time from full operational attenuation to 10dB attenuation, and should be less than 1sec. The second recovery time is defined as the return time from operational attenuation to fully deactivated state, and should be less than 1min.

Optical	Value	Comments
Linear transmission	>80%	@ 400-1700 nm
Attenuation at operation	>30dB	
Operation wavelength region	400-1700 nm	
Rise time	<30 msec	
Recovery time to 10dB attenuation	<1 sec	TBD
Recovery time to linear	<1 min	TBD

Table 1: Preliminary specifications for DSF filter

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3 DSF - EXPERIMENTS

3.1 Setup description

The setup utilized for blooming preventing demonstration and attenuation measurements is presented in Figure 3:

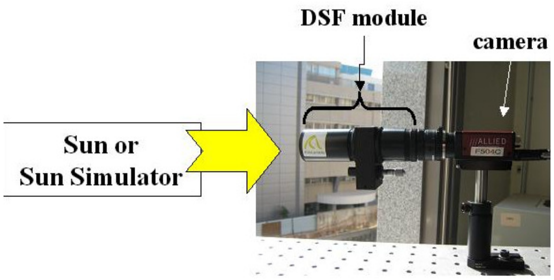

Figure 3: experimental setup scheme utilized for blooming preventing demonstration and attenuation measurements

The experimental setup is composed of a digital camera, e.g AVT Stingray F125C or F504C or Canon A75. In front of the camera we introduce an add-on module, which is composed of a 1x1 optics with ±11^o field of view. We then introduce the DSF, in the focus of the module, with the possibility of removing it for reference experiments. During the experiments, the camera together with the add-on module were directed toward the sun, or the sun simulator. In order not to be dependent only the sun, we used a sun simulator system, which simulate the solar spectrum and power density. The intensity of the sun or the sun simulator was roughly 1kW/m^2. The following camera images are presented without any software modification.

We tested the DSF integration close to the sensor using the AVT Stingray F504C, and in this case without any add-on required (Figure 4).

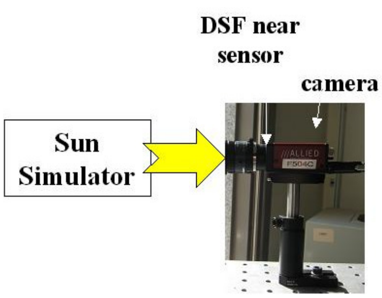

Figure 4: experimental setup scheme utilized for blooming preventing demonstration, where DSF is integrated in sensor approximation

3.2 Blooming prevention demonstration using an add-on module

The experiment was performed using the Canon A75 in Automatic mode, aligned together with the add-on module toward a building at a distance of few tens of meters. Both images that appear in Figure 5, left and right, were taken during the morning hours, looking into sunrise from behind the building. The first image, left, was taken without the DSF in the add-on module. Here the only control was the Automatic Gain Control (AGC) and other software options implemented in the Canon A75 itself. Although the camera was on automatic mode, enabling it to choose its own gain and other parameters, the picture shows a very large blooming effect and hardly no details of the building can be seen due to the saturation of the sensor. This saturation is the result of the sun over-power, which creates the blooming phenomena as we discussed in reference 12.

Next we introduced the DSF into the add-on module focus and kept all other camera parameters unchanged. By doing that, we managed to lower the blooming effect to the level where the building itself can be seen (see Figure 5, right). The improvement of the image clarity when using the DSF is demonstrated by comparing the two images (Figure 7). The image in Figure 5, left is completely saturated and therefore the building is completely hidden by the blooming effect. However, the image in Figure 5, right, has much better contrast levels with no significant blooming effect. As so, the building appears in the image with all details that could not been seen when blooming effect hidden everything.

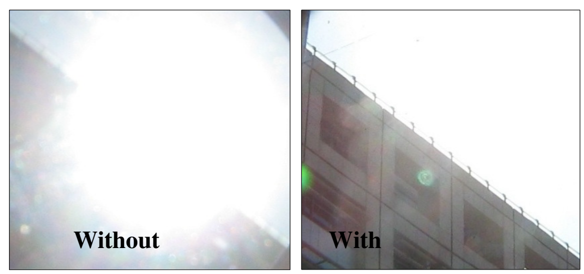

Figure 5: Image of a building with morning sun shining behind it, taken through the add-on module, **without** (left) and **with** (right) the use of the DSF

For "cleaning" the solar effect from the image, one should attenuate only the high power rays and keep the rest of the light rays at their initial power levels. This is exactly the DSF functions : above a certain threshold it limits the power passing through it to a constant level. In order to decrease only the blooming due to the sun, the DSF provides a local attenuation measured to be around 20dB. Within the rest of the filed of view, the attenuation is kept low in the order of less than 1dB.

The experimental results show a significant improvement in the image dynamic range when using the DSF. It shows that the DSF provides a passive High Dynamic Range solution for cameras that do not posses this ability.

Similar results are presented when using the AVT Stingray F504C instead of the Canon A75 (refer to Figure 6). The blooming effect, which is the white line alone the building image (left image), is reduced dramatically when using the DSF (right image). The blooming effect decreases visibility of the whole image, and not only near the saturated pixels. The effect of adding a DSF enables the user the possibility of taking pictures in front of the sun and still be able to have a reasonable clear image.

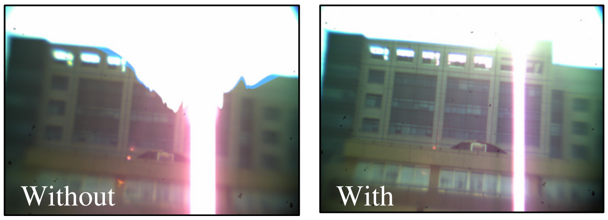

Figure 6: Image of building without (left) and with (right) DSF within an external module

3.3 DSF integrated in sensor's proximity

We repeated the experiment with AVT Stingray F504C with DSF integrated near the camera sensor itself as described in section 3.2. Results of anti-blooming effect of the DSF when the light source is a sun simulator are presented in Figure 7. The image present KiloLambda's logo as viewed through the camera without (left) and with (right) DSF integrated near the camera sensor.

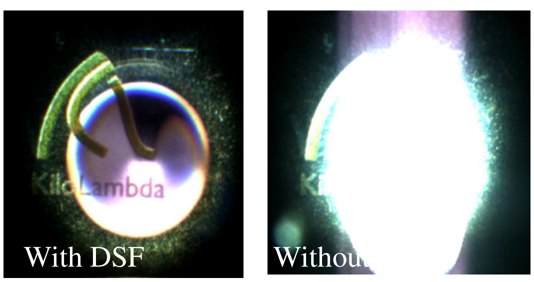

Figure 7: Image of KiloLambda's logo without (left) and with (right) DSF integrated near the sensor.

3.4 Summary

We presented several demonstrations of the DSF performance, when integrated near the sensor or in an add-on module. The reduction of blooming due to the passive operation of the DSF is clearly observed in both cases. The addition to the dynamic range of the camera is in the order of 30dB and more, and its operation is completely passive. The measured response time is within few millisecond range, enabling blooming prevention in real time applications.

4 DSF APPLICATIONS

DSF technology enables users to benefit from passive light control in few ways. The DSF element is designed to automatically vary its transparency as a function of the amount of incident light, without the need for active action of the user or electronic circuits.

For instance, in photography, shooting toward the sun creates a tremendous challenge for the camera and the photographer. A DSF, when installed in a camera, will greatly ease this problem and even allow shooting directly toward the sun. Taking a photo toward the sun will no longer result in large areas of the image that is completely "burned" (or overexposed). The DSF has the unique property that it automatically reduces its transparency in the regions of intense light to a lower level that is acceptable by the camera, permitting correct exposure of the image. As a result, the unwanted glare associated with shooting against the sun and the reduction in dynamic range of the shaded regions is eliminated. Thus images taken with a DSF will be greatly improved and reveal details that were otherwise obscured by the harsh sunlight

Digital photography is a wonderful technique, but it is not so great at handling scenes that are comprised of both very dark and very bright areas. The human eye is great at it, but the sensors in digital cameras are not. We demonstrated in this paper a passive solution to overcome this problem, and show a way to transform any camera into a High Dynamic Range imaging tool. The DSF can be incorporated in the camera, either at the level of the sensor itself, or as an add-on module. The DSF will provide the ability to control the image contrast in a passive way. One of the early adaptors will be the use of the DSF as an add-on for a security camera placed outdoors. In certain times of the day, for example, when the morning sun shines through the buildings, the camera can be completely saturated, and as so, the security system will be blind and useless for a while. When adding the DSF solution, events of zero data for periods of time are eliminated, thus increasing the reliability of the security system.

Today's battlefield has imaging systems everywhere, from simple observation and up to very sophisticate warning and offensive systems. Each imaging system has at least one camera. Since the direction of viewing is not always known and can be in certain cases in toward the sun, or another source of strong light, such events of camera blinding are very likely to occur. Adding the DSF as an add-on to the cameras, will increase their dynamic range and provide the user with the ability of continue operation even when aiming towards the sun.

DSF, optical limiter and optical fuse are KiloLambda patent pending.

REFERENCES

[1] J. Stumpfel, A. Jones, A. Wenger, and P. Debevec., 3rd International Conference on Virtual Reality, Computer Graphics, Visualization and Interaction in Africa, Stellenbosch (Cape Town), South Africa, (2004).

[2] J. Hynecek, "Electron hole recombination antiblooming for virtual phase CCD imager" IEEE Transaction of electron DEVICES, VOL. ED-30, NO. 8 (1983)

[3] R. J. Janesick, "Scientific charge coupled devices", SPIE Publishers, 273-283 (2001).

[4] TC211 192- □165-PIXEL CCD IMAGE SENSOR

[5] A. Donval, S. Goldstein, P. McIlroy, R. Oron and A. Patlakh, "Passive components for high power networks," in Optical Components and Devices, Ed.: Simon Fafard, Proc. SPIE 5577 (2004).

[6] R Oron, A. Donval, S. Goldstein, N. Matityahu, M. Oron, A. Patlakh, J. Segal and R. Shvartzer, "Optical Power Control Components in Networks," Nat. Fiber Optic Eng. Conf. (NFOEC), paper JWA75 (2005).

[7] A. N. M. M. Choudhury, B. Grzegorzewska, T. S. Hanrahan, T. R. Marrapode, A. Donval, M. Oron, R. Oron and R. Shvartzer, "Dynamic Attenuator – a New Passive Device to Control Optical Power Levels in Networks" Nat. Fiber Optic Eng. Conf. (NFOEC), paper JThA88 (2007).

[8] KiloLambda, "Image protecting limiter and switch WO 2007/042913", patent (2007).

[9] R. Oron, A. Donval, B. Nemet, M. Oron, R. Shvartzer, "IR and visible wideband protection filter," in Infrared Technology and Applications XXXII; Eds: B. F. Andresen, G. F. Fulop, P. R. Norton, Proc. SPIE 6206, (2006)

[10] A. Donval, B. Nemet, M. Oron, R. Oron, R. Shvartzer, L. Singer, C. Reshef, B. Eberle, H. Bürsing, R. Ebert, "Wideband protection filter: single filter for laser damage preventing at wide wavelength range", in Electro-Optical and Infrared Systems: Technology and Applications, Eds: Huckridge, R. Ebert, Proc. SPIE 6737 (2007).

[11] A. Donval, B. Nemet, M. Oron, R. Oron and R. Shvartzer "Nanotechnology Based Optical Power Control Devices",in nano-electronics and photonics, Proc. Nanotech 2007, Vol. 1, p. 100-103 (2007).

[12] A. Donval, T. Fisher, G. Blecher and M. Oron, "Dynamic Sunlight Filter (DSF) – A Passive Way to Increase the Dynamic Range in Visible and SWIR Cameras", in Infrared Technology and Applications XXXVI, Proc. of SPIE Vol. 7660 766024-1.