MSc in Photonics

Universitat Politècnica de Catalunya (UPC)
Universitat Autònoma de Barcelona (UAB)
Universitat de Barcelona (UB)
Institut de Ciències Fotòniques (ICFO)

http://www.photonicsbcn.eu

PHOTONICSBCN

Master in Photonics

MASTER THESIS WORK

IMPROVING THE QUALITY OF A TV SPORTS PRODUCTION USING CUSTOM POLARIZING FILTERS

Jordi Alonso Mendoza

Supervised by Dr. Artur Carnicer, (UB)

Presented on: 26th February 2015

Registered at

Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona

MSc Thesis Work

Improving the quality of a TV sports production using custom polarizing filters

Jordi Alonso Mendoza

Wavefront Engineering Research Group, Departament de Física Aplicada i Òptica, Facultat de Física, Martí i Franquès 1, 08028 Barcelona
Mediapro Research, Avinguda Diagonal 177, 08018 Barcelona

E-mail: jordi.alonso@gmail.com; jalonso@mediapro.es

Abstract
Wooden polished floors in indoor stadiums, combined with the lighting requirements of a current day broadcast production of live TV sporting content, comes with a big issue: unwanted glare and reflections from the powerful luminaries over the ground of the arena and back to the camera. This thesis performs an analysis of the particularities of a single arena: FCBarcelona's Palau Blaugrana, and its recently installed lighting system and its attempts to mitigate this issue through the use of custom designed polarizing filters.

Keywords: Live sports, TV, glare, reflections, polarization, lighting, luminaries.

1. Introduction
Nowadays, professional sport is only possible through the sponsorship and commercialization of the content through live TV broadcasts. In order to attract audiences and the advertisers, TV companies try to make their content the most attractive they can. In 2015, FullHD cameras are the standard, and HDTV sets are in almost every home, so broadcasts in FullHD are the norm. Lately, the photonics industry has brought to the TV industry a range of sensors that allow faster frame rates at a reasonable cost, bringing the possibility of slow motion even during live events. Despite the frame rates achievable being in the order of 1,000fps or even higher, the most commonly used speed for HDTV transmissions is 300fps for "Super Slow Motion" cameras[1], compared to the standard frame rate of 25 or 50fps. This high speed recording needs, on the one hand, fast arrays of disks and solid state memories, but on the other hand, it requires more light in the venue. This season 2014-15, a new lighting system has been installed in FCB's Palau Blaugrana, meeting the requirements of FIBA's[2]. The new position of the luminaries and its intensity, is producing unwanted glare and reflections on the master camera position, the most used during a TV broadcast.
AutomaticTV is a revolutionary product developed by the Mediapro Research team that will be launched in March 2015 worldwide, allowing the production of live HD content without any crew being involved - fully automatic.
Mediapro, following up on AutomaticTV, has installed a fixed panoramic camera position to cover the full arena of FCB's Palau Blaugrana as a master camera, and there, the installation of a solution like the one described in this paper would be ideal. If proven successful, it is likely that this solution will be replicated in more arenas worldwide for future installations of AutomaticTV.

2. Problem statement

If a camera is placed at the master position of the Palau Blaugrana stadium, when the lights are switched on, you get an image like the one on Figure 1.

Figure 1. Image captured without any filter applied to the camera, with the lighting in match conditions.

The glare from reflections on the wooden surface is very apparent, and it is highly distracting for the spectators watching the match on their TV sets. The application of a custom filter will minimize this unwanted glare.

3. Capture of the polarization angles

In order to calculate the optimal parameters, a sequence of images has to be captured following a precise polarization angle.

I_1 = Intensity with linear polarization at 0º
I_2 = Intensity with linear polarization at 90º
I_3 = Intensity with linear polarization at 45º
I_4 = Intensity with linear polarization at 135º
I_5 = Intensity with circular polarization at 45º
I_6 = Intensity with circular polarization at 135º

and additionally, the following polarization directions have also been captured:

I_7 = Intensity with linear polarization at 180º
I_8 = Intensity with circular polarization at 0º
I_9 = Intensity with circular polarization at 90º
I_{10} = Intensity with circular polarization at 180º

Having those captures in RGB, the luminance Y of each image has been computed from their RGB values using the formula (1):

$$Y = 0.299\, R + 0.587\, G + 0.114\, B \qquad (1)$$

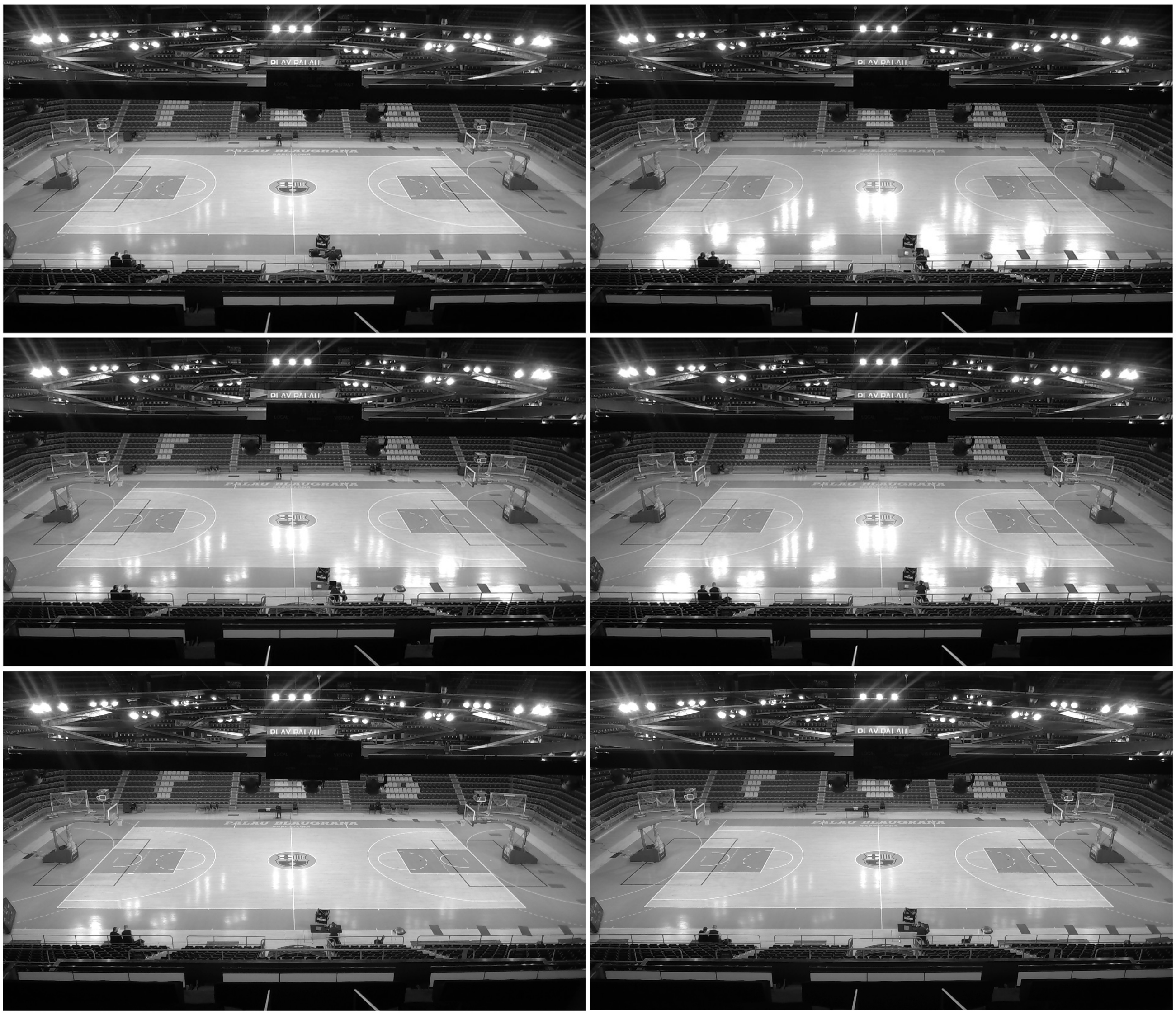

Figure 2. From left to right and from top to bottom: $I_{1\,(0º)}$ $I_{2\,(90º)}$ $I_{3\,(45º)}$ $I_{4\,(135º)}$ $I_{5\,(C45º)}$ and $I_{6\,(C135º)}$

4. Calculation of the Stokes parameters

The Stokes parameters [3-6] are computed from the luminance of the respective I_i according to expression (2)

$$
\begin{aligned}
S_0 &= I_1 + I_2 \text{ (incident irradiance)}\\
S_1 &= I_1 - I_2 \text{ (degree of horizontal/vertical (+/-) polarization)}\\
S_2 &= I_3 - I_4 \text{ (degree of polarization at 45º/135º)}\\
S_3 &= I_5 - I_6 \text{ (degree of right/left(+/-) circular polarization)}
\end{aligned}
\qquad (2)
$$

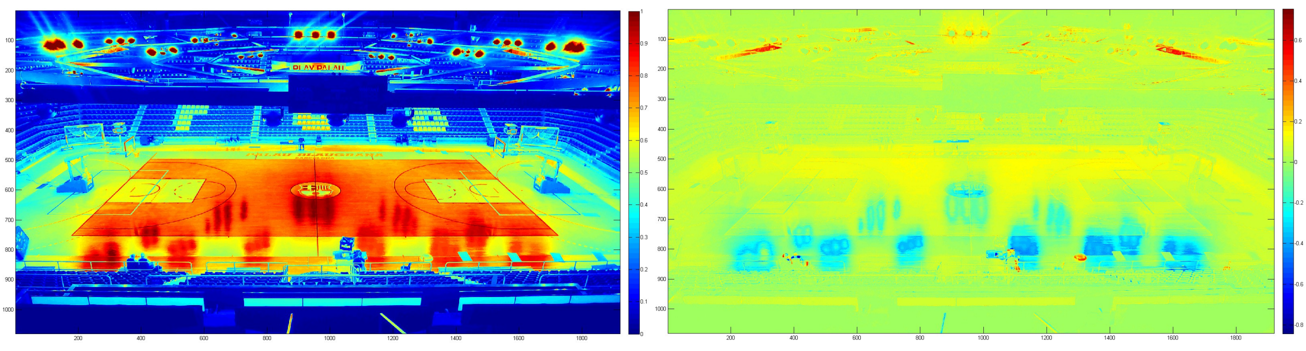

Figure 3. From left to right and in pseudocolor: S_0 and S_1

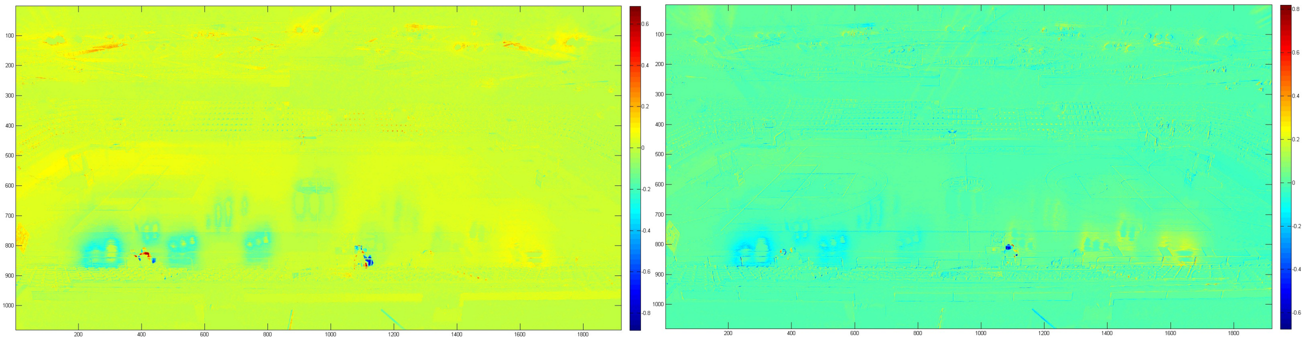

Figure 4. From left to right and in pseudocolor: S_2 and S_3

Some artifacts on the S_i are as a result of using non perfect filters, some noise on the camera sensor, and more noticeable, because of people moving into the frame during the time it took to record from the first to the last image (near pixel coordinates {450,850}, {850,400} and {850,1100}), and one person leaving an object on the floor (near pixel coordinates {850,1300}). That means that the images shown here, have not been taken in perfect circumstances, i.e. no people nor movement and thus identical conditions for all captures. The lighting was however constant and was identical to the settings for competition lighting throughout the whole recording session.

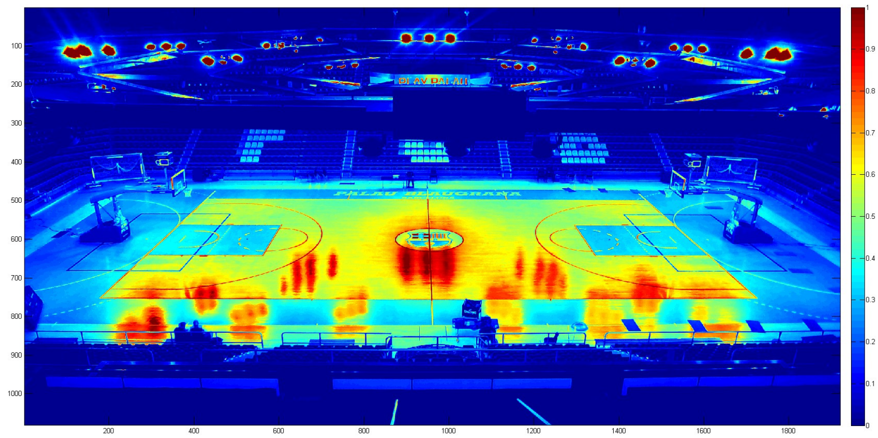

Figure 5. Complete Unpolarized Light = S_0^2

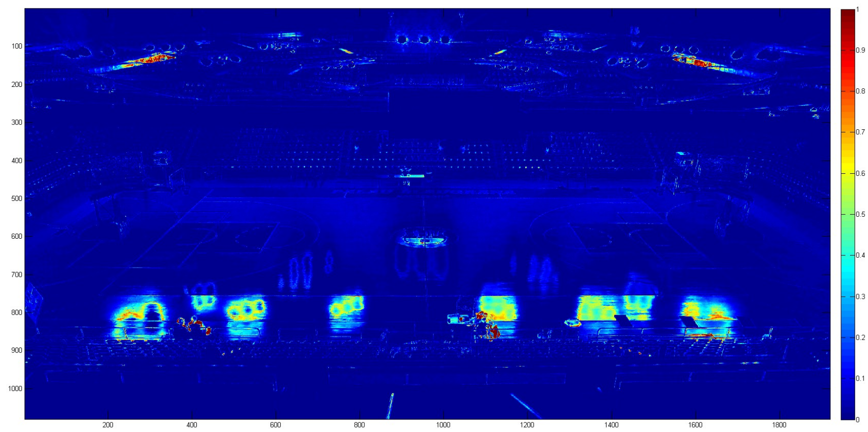

Figure 6. Complete Polarized Light = $S_1^2+S_2^2+S_3^2$

Average values (3) of the Degree of Linear Polarization (DoLP), Degree of Circular Polarization (DoCP) and Degree of Polarization (DoP)

$$\langle DoLP \rangle = \sqrt{(S_1^2+S_2^2)}/S_0 = 0.061$$

$$\langle DoCP \rangle = \sqrt{(S_3^2)}/S_0 = 0.005$$

$$\langle DoP \rangle = \sqrt{(S_1^2+S_2^2+S_3^2)}/S_0 = 0.062 \qquad (3)$$

5. Creating the custom polarizing filter

The analysis will now search for a minimum intensity value of the different polarization directions of the Stokes parameters, doing an iterative search and comparison of the minimal value for each pixel, so a composite image will include the best results for each of the original images.

Each pixel of the final composite image will take the value from the minimal intensity searched on each of the original polarization directions I_i and to avoid image artifacts, only pixels that minimize S_1 are analyzed. The final contribution of each of those images is indicated as a pseudocolor image on Figure 7, followed by the percentages of the amount of pixels of the final image covered by each I_i in (4).

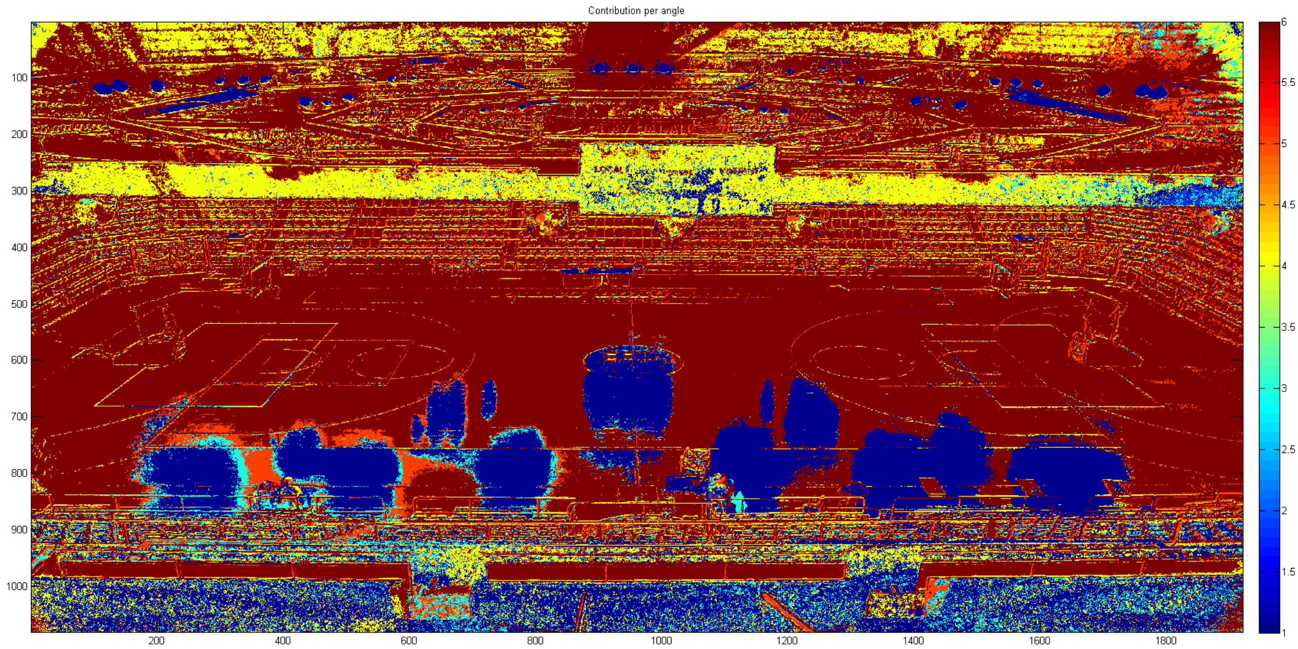

Figure 7. Pseudocolor image indicating the contribution of every single polarization direction on the final composite image (in dark blue $P_{0º}$, in yellow $P_{135º}$ and in dark red $P_{C135º}$ which are the three major contributors)

$$P_{0º} = 16.73\% \quad P_{90º} = 1.12\% \quad P_{45º} = 3.25\%$$
$$P_{135º} = 15.10\% \quad P_{C45º} = 6.54\% \quad P_{C135º} = 57.25\% \tag{4}$$

Figure 8. Composition from the 6 different images into an ideal one as would be seen through a custom filter

6. Side effects of using the polarization filters

During official matches, it is quite normal to install perimeter advertising using screens. In the case of FCB, for Basketball the technology used for the screens is based on LEDs, but in the case of Handball a set of LCDs are installed to display the publicity. These LCDs are protected by a heavy duty plastic cover to prevent breaking under heavy impact. The polarizers on camera lenses produce artifacts on the LCD screens that have this protective cover. Where more tension is present they clearly show polarization due to stress. The final images are not popular with the advertisers, so many TV companies decide to record without polarizers, and therefore lighting glare is noticeable.

Figure 9. Artifacts due to stress polarization on plastic protectors look like dirt on the LCD TVs

Figure 10. Detail of the stress polarization artifacts on LCDs when captured with a polarizing filter

Figure 11. Detail of the same LCDs captured with a neutral filter only (no polarizer)

A solution however can be achieved by combining a filter which uses the correct polarization configuration to minimize glare only on the part of the lens that covers the field, and a neutral filter to cover the area of the perimeter advertising on the upper part. A neutral filter is necessary to match the exposure of the full frame, if not, the upper part of the image would be overexposed compared to the area covered by the polarizing filter.
A schematic view of how such a filter would look, is shown on Figure 12, and the theoretical result, using digital composition, is seen on Figure 13.

Figure 12. Pseudocolor illustrating the parts of the custom filter (green: neutral density filter, blue: linear polarizer at 0º, red: circular polarizer at 135º)

Figure 13. Image generated after applying the custom neutral filter/polarizing filter to the camera

7. Conclusion
In a set-up like the one that is being installed in indoor stadiums by Mediapro, with a panoramic configuration of FullHD fixed cameras, where the only movements or zooms are digital over the composite panorama, a custom filter like the one described in this work could be used to reduce to a minimum the side effects of glare and reflections from a polished surface by installing a custom polarization filter in front of the lenses of the cameras. Because it is a permanent installation, this type of analysis can be done once by matching the lighting conditions when the cameras have been installed in their final location. Having completed the analysis, the polarising filters could be manufactured with the precise optical prescription, producing as an outcome, a significantly better final image for the broadcasting of matches.

To avoid overexposure of the upper part of the image where the perimeter LCD advertising TVs are located, a custom filter would be crafted with the combination of a neutral filter for that upper area, and with a custom polarizing filter for the rest of the image, a mixed combination that would give the best possible result and minimize the polarization artifacts.

8. Future work

This work is created using image processing techniques, by physically combining the images captured with different polarization angles, and which have been manually adjusted. The next step would be to manufacture filters based on the results shown in this work as a collage of different filters. To minimize isolated pixel contribution, a bilineal filter might be applied to the solution so it would be easier to generate more consistent areas of influence for each type of filter, making it easier to combine.

There is a further action to evaluate, which is the use of High Dynamic Range technology, by doubling the rate of capture of the video camera to 50fps (that the utilised model of camera is capable of) and by applying a very low exposure time for the first capture, and a longer one for the second, being able this way to select the pixels that are too bright on the second exposure and replace them with the ones captured with the faster first exposure, and later on, creating a new image composite of the pixels of the two images.

9. Acknowledgements

I am indebted to my thesis advisor, Professor Artur Carnicer, for his help and encouragement throughout the course of this work, to Marta Cierco as representative of the Futbol Club Barcelona by helping with the authorization for my recording sessions at the Palau Blaugrana, to my friend David Hurley, for his assistance with the English text, and last but not least, to my wife Marina, for her support and patience during the preparation of this work.

10. References

[1] OSRAM Licht AG. HDTV lighting. http://www.osram.com/osram_com/news-and-knowledge/luminaires-home/professional-trends/hdtv-lighting/index.jsp [visited last time on Nov 9th 2014]

[2] FIBA (International Basketball Federation) Rules 2014, Basketball Equipment. Chapter 17 Lighting. http://www.fiba.com/downloads/Rules/2014/BasketballEquipment2014_Final_V1_withCovers_LOW.pdf [visited last time on Nov 9th 2014]

[3] Thorn lighting Ltd. http://www.thornlighting.com/download/Handbook5-11.pdf [visited last time on Nov 9th 2014]

[4] Williamson R 2005 Polarization Optics Tutorial: Polarizers, Waveplates, Rotators and Lyot Filters. Ray Williamson Consulting. http://www.ray-optics.com [visited last time on Nov 9th 2014]

[5] Xiao X, Javidi B, Saavedra G, Eismann M, Martinez-Corral M. 2012 Three-dimensional polarimetric computational integral imaging. Optics Express. *Optical Society of America.* Vol.20 No.14 15481-15488

[6] Born M, Wolf E. 1970 Principles of Optics 4th Edition. Chapter 1: Basic properties of the electromagnetic field. 14-70. Chapter 2: Electromagnetic potentials and Polarization. 71-108. *Cambridge University Press*

11. Addendum

For a better comparison of the results, in the figures below is shown a “before” and an “after” using the custom filter

Figure 14. Image captured without any filter

Figure 15. Image obtained after applying the custom polarizing filter

Figure 16. Image captured with the polarizing filter exclusively

Figure 17. Image obtained after applying the custom neutral filter/polarizing filter