Comparison of optical transmission of APD and Pyramid WFS

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1 Scope

This document contains an analysis of the flux received by the ARGOS NGS WFSs with the comparison of SX and DX systems and APD and Pyramid WFS.
The SX APD flux is about 3 times smaller than the one measured by the SX Pyramid WFS under the same conditions. On the DX system this difference is neglectable.

2 Definitions

2.1 Trasmission efficiency

We want to quantify the transmission efficiency of the two arms of the NGS board, the Pyramid one (τ_P) and the APD one (τ_A).
We define these quantities as the ratio between the measured flux and the expected one based on theoretical computation. We keep into account 3 parameters that we have a good a priori knowledge of:

- the Filter Wheel 1 transmission,
- the Quantum Efficiency (QE) of the two detectors,
- the LUCI dichroic cutoff wavelength.

The transmission efficiencies include the contribution from atmospheric absorption, telescope and WFS optical transmission and optical misalignment and vignetting. For theoretical computation we assume spectral type G2V.

2.2 Filter Wheels

On the SX side we used two filters on the Filter Wheel 1:

- 90/10
- Dichroic 600/1000 nm

On the DX side we used two filters on the Filter Wheel 1:

- 50/50
- Dichroic 600/1000 nm

The actual transmission of the 90/10 filter used on the Filter Wheel 1 on SX side has been estimated on the base of a measurement done in August '15 during the APD installation campaign. The transmission is roughly about 15%.
From the W activity log 20150817:

lamp=46% CCD39 at 197Hz
Filter Wheel1 in POS2 (empty) => f= 10200 phot/subap
Filter Wheel1 in POS3 (90%-10%) => f= 1564 phot/subap

2.3 LUCI dichroics

LUCI dichroic on DX side reflects from 600 to 1000nm while LUCI dichroic on SX side reflects from 600 to 850nm.
In the following counts are expressed as ph/s collected by the primary (~53 m^2).

2.4 Flux estimate from Pyramid WFS

The Pyramid WFS (PWFS) estimates the magnitude of the reference star from the CCD39 counts. Counts collected per integration time and per subaperture are converted to photons/second. The conversion factor stored into a FLAO configuration file[1] relates m_0=5.5 to a flux measured on CCD39 of f_0=2.1*10^9 ph/s over the M1 area (~53 m^2). The flux for a star of magnitude m is computed as:

$$f = f_0 \cdot 10^{-\frac{m-m_0}{2.5}}$$

This conversion factor has been measured on sky during the FLAO DX commissioning campaign to have the magnitude estimated by the PWFS in agreement with the magnitude of the catalog. As such it already contains an assumption of the overall transmission efficiency τ_P. We computed τ_P=0.33 for the DX unit by comparison with theoretical expected flux (see below). We cannot rely on the same computation for the SX unit as no calibration has ever been done. Star color correction is applied; we assumed G2V spectral type when we cannot compute the color.

[1] Actually the value stored is 2.97*10^6 ph/s/$subap^{bin1}$ where $subap^{bin1}$ is the area of a subaperture at bin1 equal to 0.0747m^2.

2.5 Theoretical flux

The theoretical flux is computed using the "phot_lib" library developed in OAA that provides number of photons integrated over a given bandwidth for a star of a given spectral type and magnitude. As a reference, a G2V star of m_R= 5.5 provides in the range 600nm<λ<1000nm $8.76*10^9$ ph/s for DX side over the LBT primary.
This value doesn't account for atmospheric nor for optical transmission.
When Quantum Efficiency (QE) of the CCD39 is taken into account, we obtain an expected flux of $6.27*10^9$ ph/s for DX side over the LBT primary, from which we compute τ_P=0.33.

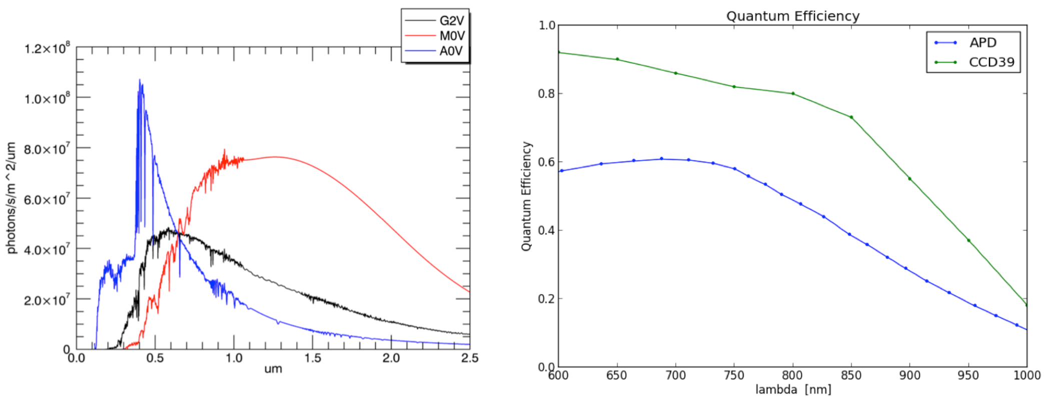

Figure 1: Flux spectrum computed for three different spectral type stars of mag_R= 8. Quantum efficiency for APD and CCD39.

3 Transmission Efficiency

We analyzed system data on SX and DX side to estimate the transmission efficiency τ_P and τ_A, for PWFS and APD respectively.
In the following Table a number of targets on SX unit are reported. Theoretical (Th) and measured (Meas) fluxes are in units of ph/s. Theoretical values take into account Filter Wheel 1 transmission, QE and LUCI dichroic cutoff wavelength.

SX			**Pyramid WFS**			**APD**		
Targets	m_R	FW1	Th	Meas	τ_P	Th	Meas	τ_A
NGC5466	13.75	90/10	369k	16.9=58k	**0.16**	1.4M	60k	**0.04**
GAL192	13.9	90/10	321k	17.0=53k	**0.17**	1.2M	55k	**0.05**
Hip49628	10.6	90/10	6.2M	14.0=836k	**0.13**	23M	1.2M	**0.05**
BD+422312	9.1	600÷1000nm	230M	9.9=36M	**0.16**			
NGC5921	m_V=16.5	90/10	45k	19.0=8.4k	**0.19**	167k	7.5k	**0.04**
NGC5921	m_V=16.5	600÷1000nm	298k	17.0=53k	**0.18**			
SDSSJ1110 +6459	15.1	90/10	101k	18.8=10k	**0.1**	377k	18k	**0.05**
SDSSJ134332	14.22	90/10	233k	17.0=53k	**0.23**	871k	60k	**0.07**

Transmission efficiency τ_P on SX unit is quite consistently in the range of 0.2 while τ_A is about a factor 3 less in all measurement excluding the target SDSSJ1110 +6459. This suggests some light loss in the APD arm of the SX unit.

DX			**Pyramid WFS**			**APD**		
Targets	m_R	FW1	Th	Meas	τ_P	Th	Meas	τ_A
Hip67995	11.1	50/50				12M	1.5M	**0.13**
NGC5272	-	50/50	-	13.0=2.1M			1.7M	
HD 5120	8.6	600÷1000nm	336M	9.6=48M	**0.14**			

On DX side the transmission efficiencies of the two sensors are comparable.

Targets	**RA**	**DEC**	**Spectral type**	m_R
NGC5466	14 05 31.373	+28 32 02.796	G2V	13.75
GAL192	05 58 15.784	+16 31 38.352	G2V	13.9
Hip49628	10 07 43.460	+23 59 30.330	F0V	10.6
BD+422312	12 29 39.514	+41 59 32.190	M1III	9.1
NGC5921	15 21 55.503	+05 04 21.072	G8V	m_V=16.5
SDSSJ1110+6459	11 10 12.961	+64 59 06.936	F5V	15.1
SDSSJ134332	13 43 38.424	+41 55 04.620	F8V	14.22
Hip 67995	13 55 28.610	+26 46 38.520	K0V	11.1
HD 5120	13 14 25.099	+45 10 49.970	F5V	8.6

3.1 APD Transmission versus Derotator angle

The transmission efficiency of the APD sensor depends on the derotator angle of LUCI. Figure 2 shows this dependency.
The reason of this effect could be due to some optical misalignment that causes a wobble of the pupil image on the APD fibers.

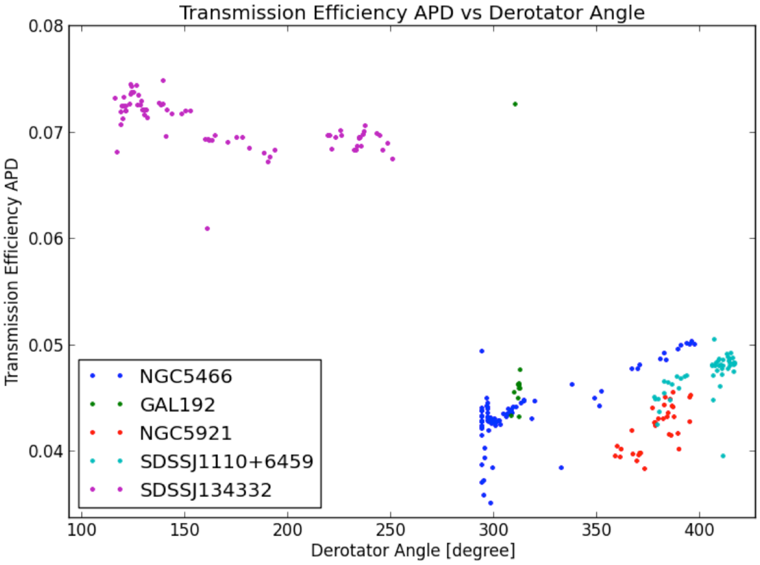

Figure 2: Transmission efficiency versus detorator angle on SX side.

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