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Optical Properties of Blocking Glass in the WFC3 IR Channel

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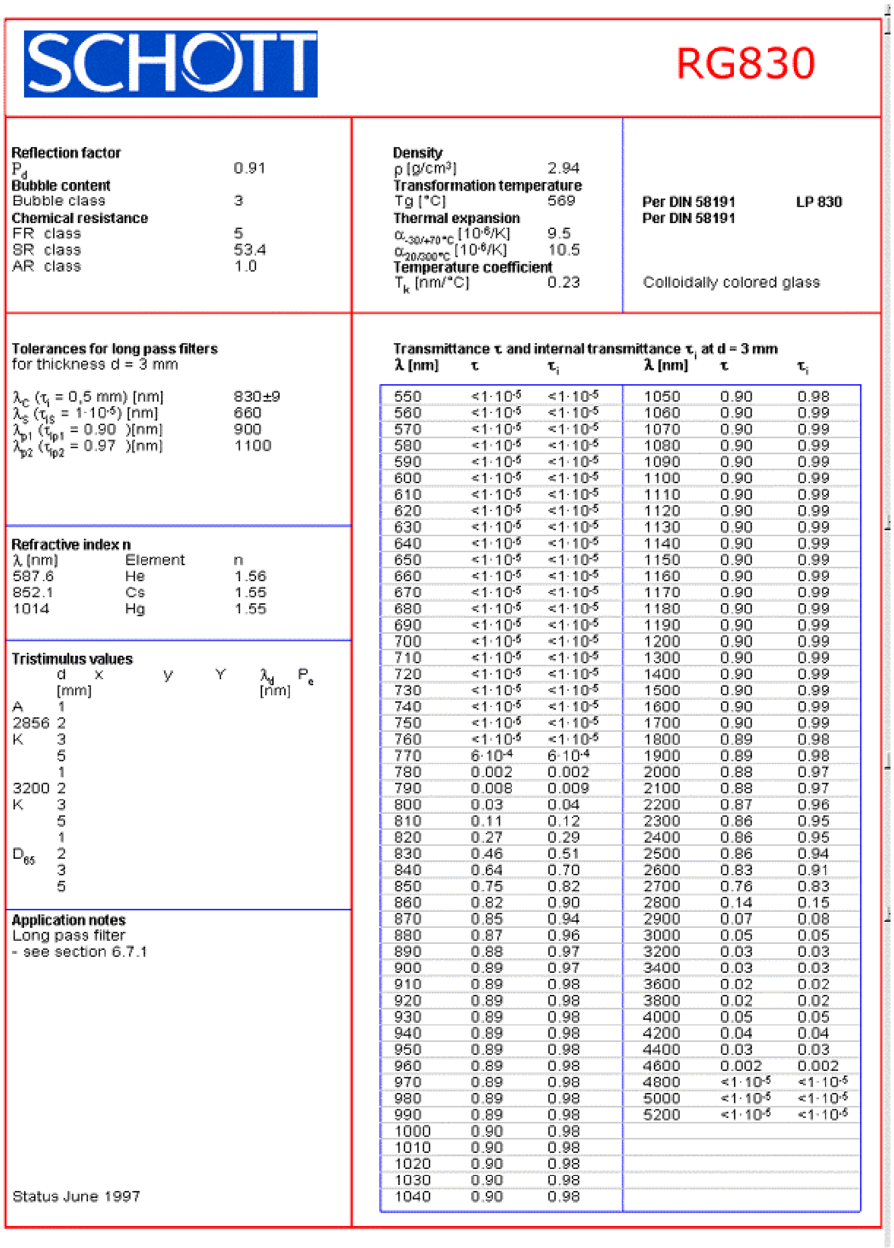
ABSTRACT
RG830 and IR80 will be used as the optical blocking glass in the WFC3/IR channel to ensure that short-wavelength (optical) light does not reach the detector. This is necessary because the substrate-removed detector will be sensitive to wavelengths below 0.8 μm. This ISR gives the expected transmission of these glasses. It also gives the maximum expected ratio of light leaking through at optical wavelengths for infrared narrow-band filters in the case that those filters provide no blocking of their own.

Introduction

The WFC3 IR channel contains a HgCdTe detector for sensing light from 0.8 µm to 1.7 µm. This type of detector is grown on a substrate to provide mechanical integrity during the manufacturing process. Examples of such substrate material include Sapphire and CdZnTe. The latter has been used for the WFC3/IR detectors. Recently, radiation testing has shown that this substrate material has an undesirable effect. It appears to produce secondary light emission when struck by high energy protons. Because of this effect, the substrate will be removed from the flight detector. When this is done, the detector will be sensitive to optical light, at least down to 400 nm. Because of this, the infrared channel optical train must contain an optical blocking filter. In fact, most of the filters are deposited on 3.66 mm thick IR80; the exceptions are F093W, F110W, and F125W, which are on fused silica.

In the future, any replacements will be made of RG830. The following web page gives transmission characteristics of 3 mm thick RG830, as given by Schott. *http://www.optical-filters.com/rg830.html*

The contents of this web page are reproduced below. As can be seen, the transmission through RG830 is very low at wavelengths below about 760 nm, thus providing blocking at optical wavelengths.



SCHOTT

RG830

Reflection factor	
P_d	0.91
Bubble content	
Bubble class	3
Chemical resistance	
FR class	5
SR class	53.4
AR class	1.0

Density	
ρ [g/cm³]	2.94
Transformation temperature	
Tg [°C]	569
Thermal expansion	
$\alpha_{-30/+70°C}$ [10^{-6}/K]	9.5
$\alpha_{20/300°C}$ [10^{-6}/K]	10.5
Temperature coefficient	
T_k [nm/°C]	0.23

Per DIN 58191	**LP 830**
Per DIN 58191	

Colloidally colored glass

Tolerances for long pass filters
for thickness d = 3 mm

λ_C (τ_i = 0,5 mm) [nm]	830±9
λ_S (τ_{is} = $1 \cdot 10^{-5}$) [nm]	660
λ_{p1} (τ_{ip1} = 0.90)[nm]	900
λ_{p2} (τ_{ip2} = 0.97)[nm]	1100

Refractive index n

λ [nm]	Element	n
587.6	He	1.56
852.1	Cs	1.55
1014	Hg	1.55

Tristimulus values

	d [mm]	x	y	Y	λ_d [nm]	P_e
A	1					
2856	2					
K	3					
	5					
	1					
3200	2					
K	3					
	5					
	1					
D_{65}	2					
	3					
	5					

Application notes
Long pass filter
- see section 6.7.1

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Transmittance τ and internal transmittance τ_i at d = 3 mm

λ [nm]	**τ**	**τ_i**	**λ [nm]**	**τ**	**τ_i**
550	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1050	0.90	0.98
560	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1060	0.90	0.99
570	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1070	0.90	0.99
580	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1080	0.90	0.99
590	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1090	0.90	0.99
600	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1100	0.90	0.99
610	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1110	0.90	0.99
620	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1120	0.90	0.99
630	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1130	0.90	0.99
640	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1140	0.90	0.99
650	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1150	0.90	0.99
660	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1160	0.90	0.99
670	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1170	0.90	0.99
680	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1180	0.90	0.99
690	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1190	0.90	0.99
700	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1200	0.90	0.99
710	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1300	0.90	0.99
720	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1400	0.90	0.99
730	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1500	0.90	0.99
740	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1600	0.90	0.99
750	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1700	0.90	0.99
760	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1800	0.89	0.98
770	$6 \cdot 10^{-4}$	$6 \cdot 10^{-4}$	1900	0.89	0.98
780	0.002	0.002	2000	0.88	0.97
790	0.008	0.009	2100	0.88	0.97
800	0.03	0.04	2200	0.87	0.96
810	0.11	0.12	2300	0.86	0.95
820	0.27	0.29	2400	0.86	0.95
830	0.46	0.51	2500	0.86	0.94
840	0.64	0.70	2600	0.83	0.91
850	0.75	0.82	2700	0.76	0.83
860	0.82	0.90	2800	0.14	0.15
870	0.85	0.94	2900	0.07	0.08
880	0.87	0.96	3000	0.05	0.05
890	0.88	0.97	3200	0.03	0.03
900	0.89	0.97	3400	0.03	0.03
910	0.89	0.98	3600	0.02	0.02
920	0.89	0.98	3800	0.02	0.02
930	0.89	0.98	4000	0.05	0.05
940	0.89	0.98	4200	0.04	0.04
950	0.89	0.98	4400	0.03	0.03
960	0.89	0.98	4600	0.002	0.002
970	0.89	0.98	4800	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
980	0.89	0.98	5000	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
990	0.89	0.98	5200	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
1000	0.90	0.98			
1010	0.90	0.98			
1020	0.90	0.98			
1030	0.90	0.98			
1040	0.90	0.98			

Figure 1. Characteristics of RG830 glass from Schott.

Figure 2 shows the optical density (OD) of 3mm thick witness sample of IR80, as measured at GSFC. Note that OD= –LOG(T), i.e. OD=0 for 100% transmission.

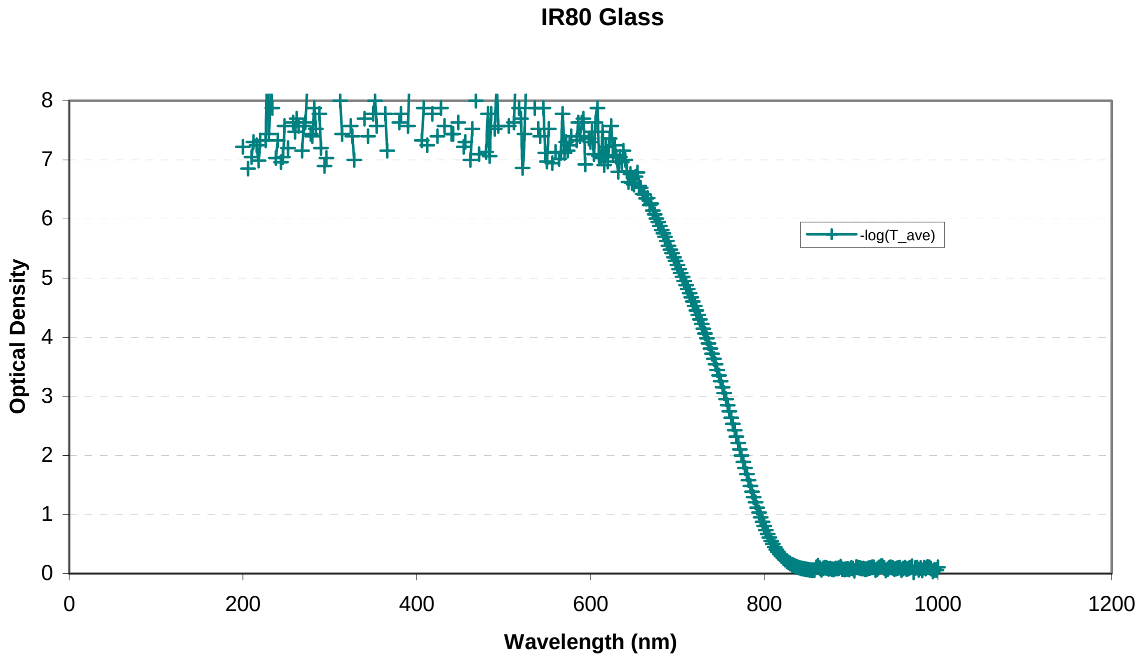

Figure 2. Optical density of 3mm thick IR80, as measured at GSFC.

Model

Does the blocking glass provide “enough” blocking? To answer this question, we wrote a program (see Appendix) to count the number of photons in an optical bandpass that make it to the detector after having passed through the blocking glass, and assuming no out-of-band blocking from the infrared filter in the WFC3/IR channel beam. To take an extreme case, we assumed an O-star, using a non line-blanketed Kurucz model, and a narrow-band (R=100) infrared filter.

Figure 3 shows the result of this calculation. The “leakage” percentage increases with wavelength because the number of in-band photons decreases at longer wavelengths for the chosen source (O-star). In all cases, the percentage is less than 0.1% for an out of band transmission of 1e-6. We also simulated the effects for an A-type star and found results about a factor of two lower in leakage percentage. Of course, the realized leakage should be much less, given that the narrow-band filters should provide some amount of blocking on their own.

Conclusions

Contamination from a “blue leak” in the WFC3 filters should provide little contamination to photometry, certainly less than 0.1% for the hottest sources.

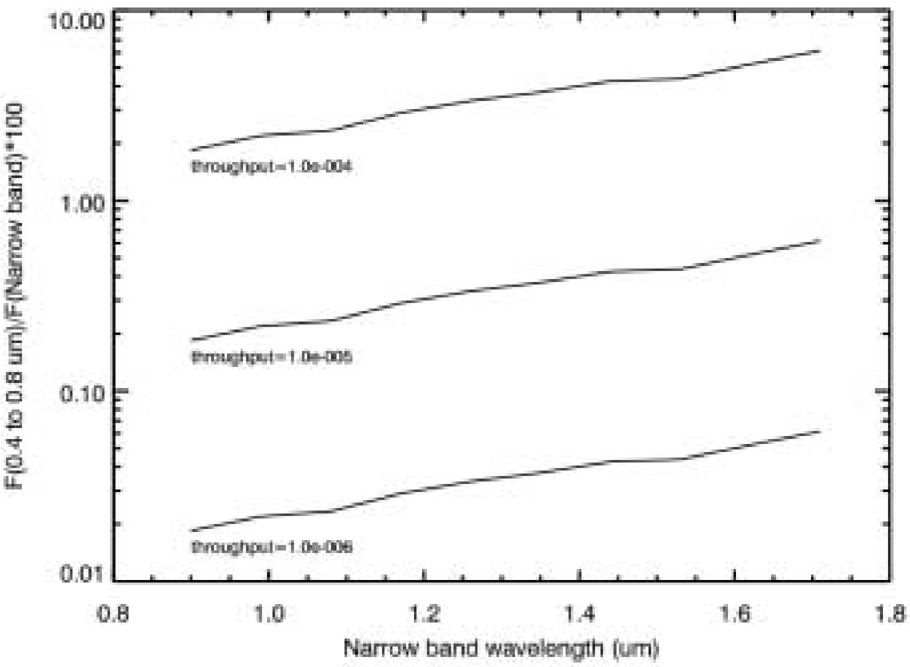

Figure 3. Percentage of number of photons through RG830 within 400 and 800 nm versus the number transmitted through an R=100 narrow-band filter versus center wavelength.

Appendix

```
pro RG830ratio
; This program computes the ratio of out-of-band flux to in-band flux, assuming
; a WFC3/IR filter and RG830 blocking glass.

        set_plot,'ps'
        device,file='ratios.ps',/landscape
        !p.thick=5.0
        !p.charsize=1.4
        !x.thick=8.0
        !y.thick=8.0
        !p.charthick=6
        !P.FONT=1
        !X.CHARSIZE=1.4
        !Y.CHARSIZE=1.4

        ; set integration limits
        RG830lambda2=8000.*1.e-8                                           ; cm
        RG830lambda1=4000.*1.e-8                                           ; cm

        plot,[0.8,1.8],[0.1,100],xrange=[0.8,1.8],xtitle='Narrow band wavelength
(um)',/nodata,/ylog,$
                ytitle='F('+strtrim(string(RG830lambda1/1e-4,format='(F3.1)'),2)+' to
'+strtrim(string(RG830lambda2/1.e-4,format='(F3.1)'),2)+' um)/F(Narrow band)*100'

        ; set range of possible throughputs
        throughputs=[1e-4,1e-5,1e-6]

        ; loop over possible throughputs
        for z=0,2 do begin
                lambdanarrowcenters=9000*1.e-8*(1+indgen(10)/10.)                 ; cm

                cd,'c:\figerdev\WFC3

                ; read in stellar energy distribution for hot (50,000 K) star from
http://www.stsci.edu/science/starburst/Kurucz.html
                ; l is in angstroms, and f is in erg/s/cm/cm/A
                ;readcol,'t50000g50p00.dat',l,f
                readcol,'t50000g50p00.dat',l,f

                ; increase density of points by a factor of 100
                newl=interpol(l,indgen(n_elements(l)),indgen(n_elements(l)*100)/100.)
                f=interpol(f,indgen(n_elements(l)),indgen(n_elements(l)*100)/100.)
                l=newl

                ; define constants
                h=0.0000000000000000000000000066260755      ; erg*s
                c=3.e10                                                           ; cm/s
                lambda=l*1e-10*100                                         ; cm
                nu=c/lambda
                dlambda=(lambda(1:n_elements(lambda)-1)-lambda(0:n_elements(lambda)-2))/1e-8 ;
A
                dnu=-c/lambda(1:n_elements(lambda)-1)+c/lambda(0:n_elements(lambda)-2)
                dnu=[dnu,dnu(n_elements(dnu)-1)]
                dlambda=[dlambda,dlambda(n_elements(dlambda)-1)]
                photons=f/(h*nu)*dlambda                           ; photons/s/cm/cm

                ; define vector of transmission values for all lambda
                RG830throughput=fltarr(n_elements(l))
                RG830throughput(*)=throughputs(z)

                ; integrate flux through RG830 glass
                RG830region=where(lambda lt RG830lambda2 and lambda gt RG830lambda1)
                RG830photons=total(photons(RG830region)*RG830throughput(RG830region))

                ; loop over set of narrow band filters
                ratios=fltarr(n_elements(lambdanarrowcenters))
                for i=0,n_elements(lambdanarrowcenters)-1 do begin

                        ; define infrared narrow band filter and integrate flux through it,
assuming 100% transmission
                        lambdanarrowcenter=lambdanarrowcenters(i)
                        bandpassnarrow=lambdanarrowcenter/100.
                        narrowregion=where(lambda gt lambdanarrowcenter-bandpassnarrow/2. and
lambda lt lambdanarrowcenter+bandpassnarrow/2.)
                        narrowphotons=total(photons(narrowregion))
```

```
                        ; store result
                        ratios(i)=rg830photons/narrowphotons*100.

                        ; print result
                        print,'ratio= ',ratios(i),'%',format='(A,F5.2,A)'

                endfor

                ; plot data
                oplot,lambdanarrowcenters*1e4,ratios

        xyouts,lambdanarrowcenters(0)*1e4,ratios(0)/1.3,'throughput='+strtrim(string(throughpu
ts(z),format='(e11.1)'),2)

        endfor

        device,/close

end
```