

Optical filter selection guide

From the light you must pass and the light you must block to a request for quote

Jezdan Gomez

JEZDANGOMEZ.COM

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Abstract.

A filter can meet its datasheet and still fail in the instrument. Three causes recur: blockers that face each other do not add, the passband moves when the beam is tilted or converging, and a bandwidth chosen for a collimated beam is too narrow for a cone. This guide follows one narrow bandpass filter, NB-532-3-B, from the job (what to pass, what to block, what beam) to a specification sheet. Two OD 5 filters mounted parallel give OD 5.30, not OD 10.00. The same 532 nm part tilted 10° in an f/2 beam passes 25 % of a 532 nm line, not 90 %. Every number is computed, and the two calculators on jezdangomez.com reproduce the equations.

1. Filter types on one page

Almost every request is one of six types. They differ in what the specification must state at the edges, not in how they are made: all but neutral density are multilayer interference coatings, while neutral density filters are usually a metal film or absorbing glass. Macleod [1] treats neutral metal films in ch. 5, edge and notch filters in ch. 7 and band-pass filters in ch. 8. Table 1 lists what to state for each, and Figure 1 draws them. The example in every section is NB-532-3-B, a narrow bandpass filter from a fictional family; Table 2 gives its specification, each value with its condition.

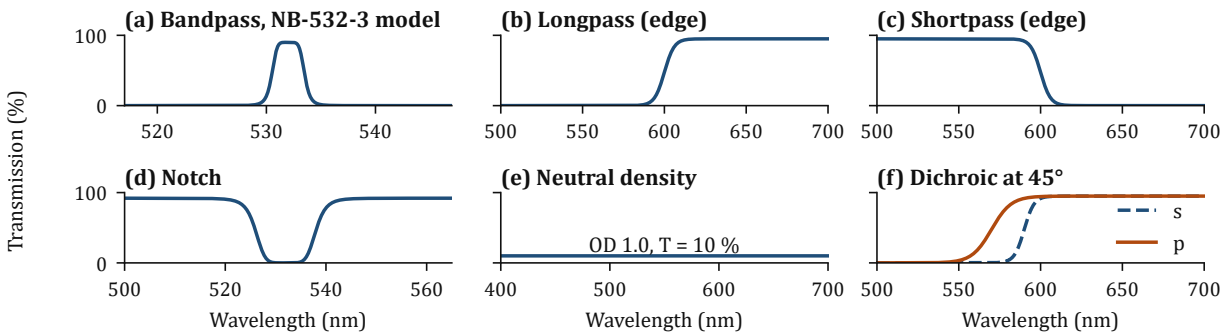


Figure 1. The six types, transmission against wavelength. Panel (a) is the typical model curve of the example filter (Eq. 11); (b) to (f) are schematic, not data from any product.

Table 1. The six filter types, what each passes, and what a specification must state for each.

Type	Passes	Specify	Typical job
Bandpass	One band around a center wavelength	Center wavelength (CWL) and tolerance, FWHM, peak transmission, blocking range and OD	Isolating a laser line, fluorescence or Raman band
Longpass	Everything above a cut-on wavelength	Cut-on at 50 % of the passband, edge steepness, blocking OD below the edge	Emission filter that rejects the excitation laser
Shortpass	Everything below a cut-off wavelength	Cut-off at 50 %, edge steepness, blocking OD above the edge	Removing infrared from a visible detector
Notch	Everything except one band	Notch center, width at a stated OD, passband transmission on both sides	Rejecting a laser line while keeping the spectrum around it
Neutral density	A range, attenuated by a fixed factor	OD and its flatness over the range, reflective or absorbing	Bringing a beam into a detector's linear range

Type	Passes	Specify	Typical job
Dichroic beamsplitter	One side of an edge in transmission, the other in reflection	Edge wavelength at 45° for s and p, reflected wavefront, polarization split	Combining or separating two wavelength bands in one beam path

2. The specifications that matter

A specification without its condition cannot be tested, and two suppliers can both be right about a number that means different things. Table 2 is the list to ask for.

Table 2. What to ask for, the condition that must come with it, and the value for NB-532-3-B (Sespe Optics, fictional).

Parameter	State	Condition that must accompany it	NB-532-3-B
Center wavelength	Min, typ and max; how CWL is defined	AOI, temperature, polarization, beam diameter; CWL is the midpoint of the half-maximum points, not the peak	531 / 532 / 533 nm at AOI 0°, 23 °C, unpolarized, 2 mm collimated beam
Bandwidth	FWHM, min and max	Same conditions as CWL	2.6 / 3.0 / 3.4 nm
Peak transmission	Minimum	At λ_0 , AOI 0°; whether the rear-face coating is counted	85 min, 90 typ %
Blocking	OD, wavelength range, exclusion zone	Range and zone stated; AOI 0°; the measurement limit of the instrument	OD 5 min, OD 6 typ, 400 to 1100 nm outside CWL $\pm$ 12 nm; limit OD 6.5
Transition	OD at stated offsets from CWL	Typical values	OD 3 at $\pm$ 5 nm; OD 5 at $\pm$ 12 nm
Effective index	n_{eff} , min and max, and the angles it was fitted at	Polarization state; fitted from measured curves, not from layer indices	2.0 typ (1.9 to 2.1), average polarization, fitted at 10° and 20°
Beam	Working f-number or cone half-angle; AOI range	The passband width in that beam, if different from collimated	Collimated: 2 mm beam; cone: see section 4
Temperature	CWL coefficient; operating and storage range	Coefficient over a stated range	+4 typ, +6 max pm/K, 23 to 70 °C; -20 to +70, -40 to +85 °C
Size	Mounted diameter, clear aperture, thickness	Tolerances; which face is coated	25.0 mm, CA 21.0 mm, 2.0 mm fused silica; coated face toward the source
Surface quality	Scratch-dig, per a named standard	MIL-PRF-13830B or ISO 10110-7	60-40
Wavefront and wedge	Transmitted wavefront; wedge	Wavelength and aperture of the wavefront test	$\lambda/4$ at 633 nm over CA; wedge under 3 arcmin
Laser damage	Fluence or irradiance	Wavelength, pulse length, repetition rate, beam size	0.5 J/cm ² at 532 nm, 10 ns, 20 Hz; 1 kW/cm ² CW

Three lines cause most disputes. *Center wavelength* is the midpoint of the half-maximum points, because a flat-topped passband has ripple and its highest point can sit off center (Figure 6). *Blocking* is limited by the instrument that measured it: a spectrophotometer with a dynamic range of OD 6.5 cannot verify OD 7. *Effective index* belongs to the coating design, not the materials, and sets how far the passband moves with angle (section 4). Every value in the first rows holds for a collimated beam at normal incidence and changes in a cone.

3. Optical density and blocking, including stacks of filters

Optical density is $OD = -\log_{10} T$ at the wavelength to block. For one filter, the transmittance T and reflectance R follow from the OD and from ρ , the share of the blocked light the filter reflects rather than absorbs: close to 1 for an interference blocker, about 0.04 for absorbing glass whose only reflections are its two surfaces (uncoated glass of index 1.5). Here ρ is a fraction; the calculator takes it in percent.

$$T_i = 10^{-OD_i} \quad R_i = \rho_i (1 - T_i) \quad (1)$$

If light reflected by one filter can never get back into the beam, the transmittances multiply and the optical densities add:

$$OD_{\text{sup}} = \sum_{i=1}^3 OD_i \quad (2)$$

That is the number on a supplier's quote for a stack, and it holds only for the layouts of Figures 3b and 3c. Mounted parallel, light reflected by filter 2 returns to filter 1, is reflected again, and gets another chance to leak. Adding the multiple reflections incoherently, as for separate components [1], gives

$$D_{12} = 1 - R_1 R_2 \quad T_{12} = \frac{T_1 T_2}{D_{12}} \quad R_{12} = R_2 + \frac{T_2^2 R_1}{D_{12}} \quad (3)$$

where R_{12} is the reflectance of the first pair seen from the third filter, and the OD of the stack is

$$D_{123} = 1 - R_{12} R_3 \quad OD_{\text{par}} = OD_{\text{sup}} + \log_{10} D_{12} + \log_{10} D_{123} \quad (4)$$

For two reflective filters, $R \approx 1 - T$, so $D_{12} \approx T_1 + T_2$, and two equal filters transmit half of what one does: the OD rises by only $\log_{10} 2 = 0.30$, not by the OD of the second filter. Two OD 5 filters give OD 5.30 in parallel against 10.00 with reflections removed, a loss of 4.70; two OD 4 filters give 4.30. A weaker partner adds nothing: an OD 2 reflective filter beside an OD 5 leaves OD 5.00 (Figure 2b), and a third OD 2 filter added to the OD 5 pair still leaves 5.30. Absorbing glass behaves the other way: two OD 5 filters with $\rho = 4\%$ give 9.9993, so the ODs add.

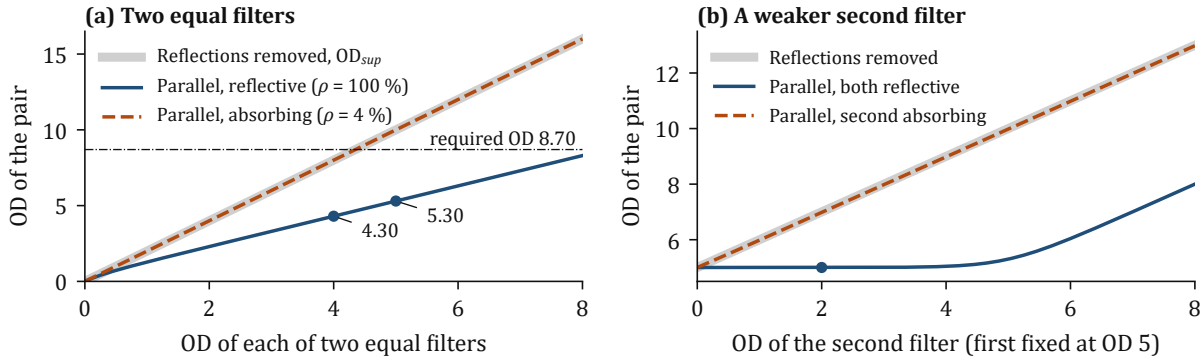


Figure 2. Stack OD against filter OD, from Eqs. 1 to 4. (a) Two equal filters; (b) a first filter fixed at OD 5 and a second of increasing OD. Reflective filters have $\rho = 100\%$; absorbing glass has $\rho = 4\%$ and lies on the line for removed reflections. The marked points are the cases in the text.

The budget decides which case matters. The required OD follows from the power at the wavelength to block and the power the rest of the system tolerates, and the margin and the OD each of n equal filters must carry follow from it:

$$OD_{\text{req}} = \log_{10} \left(\frac{P_{\text{in}}}{P_{\text{allowed}}} \right) \quad P_{\text{leak}} = P_{\text{in}} 10^{-OD_{\text{stack}}} \quad (5)$$

$$M = OD_{\text{stack}} - OD_{\text{req}} \quad OD_{\text{each}} = \frac{OD_{\text{req}}}{n} \quad (6)$$

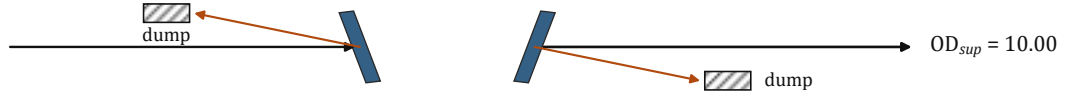
For 500 mW and 1 nW, $OD_{\text{req}} = 8.70$. With the reflections removed, two OD 5 filters pass 0.0500 nW, a margin of 1.30; parallel, they pass 2.50×10^3 nW (2.5 μ W), a margin of -3.40, and fail. The budget needs OD 4.35 from each of two filters when the reflections are removed, but OD 8.40 from each when they sit parallel, above the OD 6.5 an ordinary spectrophotometer can verify.

Remove the reflections in one of three ways (Figure 3): tilt one or both filters so the reflection goes to a dump, put an absorbing element between reflective filters, or space and baffle them. Tilting moves the passband, so check the shift with Eq. 7, and verify the OD at the tilt used. The calculator at <https://jezdangomez.com/calculators/optical-density-stack/> reproduces Eqs. 1 to 6 with the defaults used here [3]; it evaluates the loss terms in a form that does not cancel at high OD.

(a) Parallel filters: light bounces between them



(b) Tilted filters: reflections leave the beam (tilt exaggerated)



(c) Absorbing element between the filters

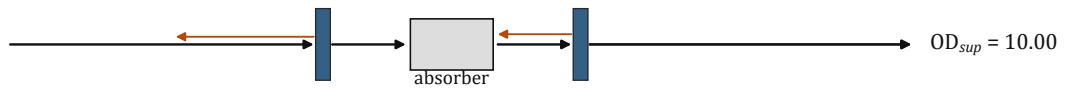


Figure 3. Three ways to mount two filters. (a) Parallel: light reflected by each filter returns to the other. (b) Tilted: reflections leave the beam (tilt exaggerated). (c) An absorber between the filters stops the reflections. The OD values are those of two OD 5 reflective filters.

4. Angle of incidence, and converging and diverging beams

4.1 Tilt

An interference filter tilted from normal incidence moves its passband to shorter wavelengths. The single effective-index model of Lissberger and Wilcock [2] describes it:

$$\lambda(\theta) = \lambda_0 \sqrt{1 - \left(\frac{n_0 \sin \theta}{n_{\text{eff}}} \right)^2} \quad (7)$$

where n_0 is the index of the medium the light arrives from, θ the angle in that medium and n_{eff} the effective index of the coating. For the example filter (532 nm, n_{eff} 2.0, in air) at 10° , $\lambda = 529.991$ nm: a shift of -2.009 nm, which is 0.378 % of λ_0 and 67 % of the 3 nm bandwidth. The shift grows roughly as θ^2 : -0.51 , -4.47 , -7.84 , -16.89 , -34.36 and -52.46 nm at 5° , 15° , 20° , 30° , 45° and 60° , and no tilt reaches below $\lambda(90^\circ) = 460.73$ nm. A lower effective index moves the passband faster: at 60° the ratio λ/λ_0 is 0.901, 0.884 and 0.802 for n_{eff} 2.00, 1.85 and 1.45 (Figure 4a).

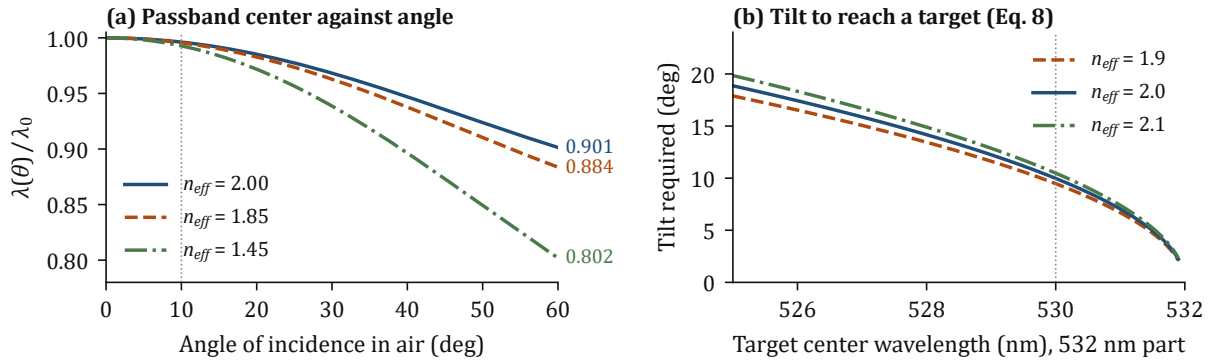


Figure 4. (a) Passband center relative to its value at normal incidence against angle in air, from Eq. 7, for three effective indices; the dotted line marks 10° . (b) Tilt needed to move a 532 nm filter to a target wavelength, from Eq. 8, for the family's effective index range of 1.9 to 2.1.

Inverting Eq. 7 gives the tilt that places a filter on a target wavelength, the basis for ordering a part slightly long and tilting it into place:

$$\theta_t = \arcsin \left[\frac{n_{\text{eff}}}{n_0} \sqrt{1 - \left(\frac{\lambda_t}{\lambda_0} \right)^2} \right] \quad (8)$$

To move the 532 nm part to 530.0 nm takes $\theta_t = 9.98^\circ$. The effective index belongs to the coating design, and the family allows 1.9 to 2.1: the same target then needs 9.47° to 10.48° (Figure 4b), so make the final setting while watching the transmitted line.

4.2 Converging and diverging beams

A focused or diverging beam of working f-number N contains rays at angles up to the half-angle α ; for $f/2$, $\alpha = 14.04^\circ$. With the cone axis tilted by θ , the steepest ray is at $\theta + \alpha$ and the shallowest at $\theta - \alpha$, or at normal incidence when the cone contains the normal:

$$\alpha = \arctan \left(\frac{1}{2N} \right) \quad \theta_{\text{hi}} = \theta + \alpha \quad \theta_{\text{lo}} = \max(\theta - \alpha, 0) \quad (9)$$

The spread of center wavelengths across the cone is $\text{Spread} = \lambda(\theta_{\text{lo}}) - \lambda(\theta_{\text{hi}})$. The pupil-averaged shift of a uniformly filled circular pupil has a small-angle estimate, exact for small angles at normal incidence:

$$\Delta\lambda_{\text{cone}} \approx - \frac{\lambda_0 (n_0 \alpha)^2}{4n_{\text{eff}}^2} \quad (10)$$

At normal incidence in an $f/2$ cone the steepest ray gives 528.07 nm, and the mean shift is -2.00 nm by integrating over the pupil against -2.00 nm from Eq. 10: they agree to the two decimals printed. Tilt the filter by 10° and the steepest ray is at 24.04° : 520.850 nm, an edge shift of -11.150 nm, while the shallowest ray stays at normal incidence, so the center wavelengths spread over 11.15 nm. The mean shift is -3.93 nm exactly and -4.00 nm from Eq. 7 plus Eq. 10, slightly pessimistic because the two terms are not independent (Figure 5). A 3 nm passband cannot pass a line across an 11 nm spread (section 5). In a medium of index n_0 above 1, such as a cement or immersion fluid, use n_0 in Eqs. 7 and 10.

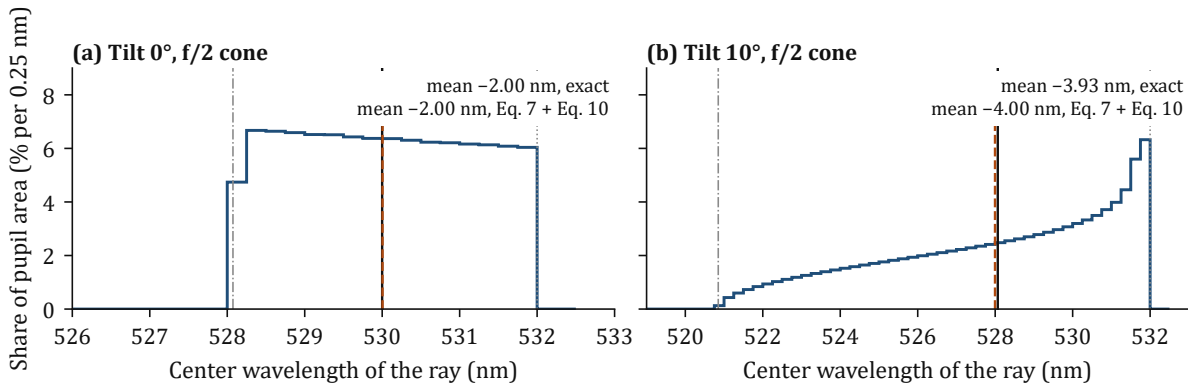


Figure 5. Center wavelength of the rays across a uniformly filled $f/2$ pupil for the example filter (532 nm, $n_{\text{eff}} 2.0$), at 0° and 10° tilt. Dotted: 532 nm; dash-dot: steepest ray; solid: exact pupil mean; dashed: Eq. 7 plus Eq. 10. Polar quadrature over the pupil, plane of tilt in the figure.

4.3 The s and p split

The single-index model is a good description at small and moderate angles for one polarization state, and only approximate beyond. A transfer-matrix calculation of a representative design (Figure 6) shows why. At 20° the s and p centers differ by 0.07 nm. At 45° the s passband is at 500.61 nm with a FWHM of 1.85 nm and the p passband at 499.00 nm with 5.34 nm: 1.61 nm apart and 2.9 times wider. The single-index model, fitted at 10° and 20° , misses the 45° centers by 0.4 nm (s) and 0.9 nm (p). Above about 20° , state the polarization and the angle together and ask for

measured curves at the angle you use (Macleod, ch. 9 and 10 [1]). The calculator at <https://jezdangomez.com/calculators/aoi-shift/> reproduces Eqs. 7 to 10 [4].

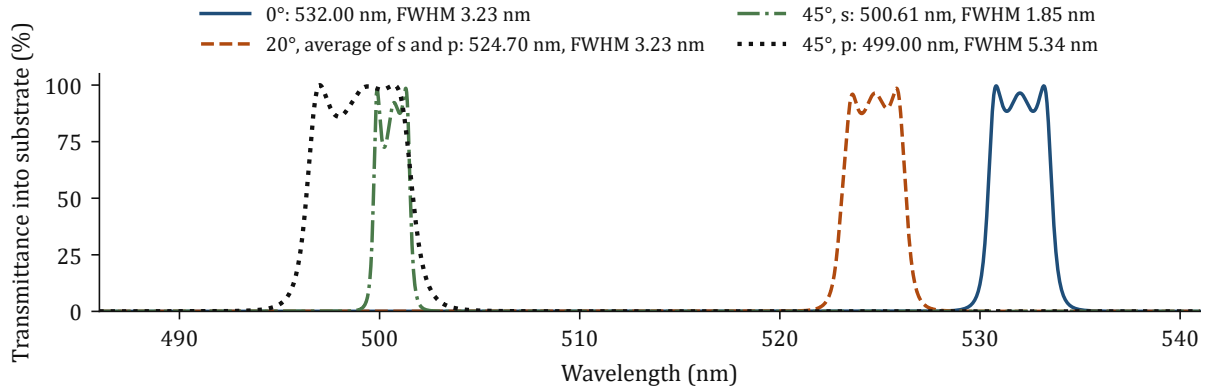


Figure 6. Transmittance into the substrate of a representative three-cavity design (41 layers, indices 2.30 and 1.46, fused silica substrate), by transfer matrix. Fitted effective index 2.07 (s 2.077, p 2.068); the family's declared value is 2.0. The legend gives the center wavelength and FWHM, measured at the half-maximum points.

5. Bandwidth and edge steepness

The passband of the example filter is drawn from a flat-topped model, the shape a three-cavity coating approaches:

$$T(\lambda) = \frac{T_{pk}}{1 + \left(\frac{\lambda - CWL}{FWHM/2} \right)^{2m}} + 10^{-OD_b} \quad (11)$$

With $m = 3$ the width at half maximum equals the FWHM, and the floor is the typical OD 6 blocking. Eq. 11 models a typical curve; it is not a coating design. It gives $T = 6.57 \times 10^{-4}$ (OD 3.2) at 5 nm from center and 4.43×10^{-6} (OD 5.35) at 12 nm, which is why the transition is specified as OD 3 at ± 5 nm and OD 5 at ± 12 nm, and the blocking range starts outside $CWL \pm 12$ nm.

Specify edge steepness as a distance: from the point where transmittance has fallen to 80 % of the peak to the point where it reaches OD 3, on one side. For the model that is 1.19 nm to 4.66 nm from center, a run of 3.47 nm; for the three-cavity design, 1.44 to 4.11 nm, a run of 2.67 nm. A single cavity is different in kind: FWHM 2.11 nm, peak 96.5 % and 15 layers, with the 80 % point at 0.53 nm but skirts that touch OD 3 only at 51.8 nm (Figure 7). Each added cavity squares the passband and costs layers: the three-cavity design has 41. Its mirrors block only between about 470 and 613 nm, so blocking from 400 to 1100 nm needs a separate coating and is its own line in the specification (Table 2).

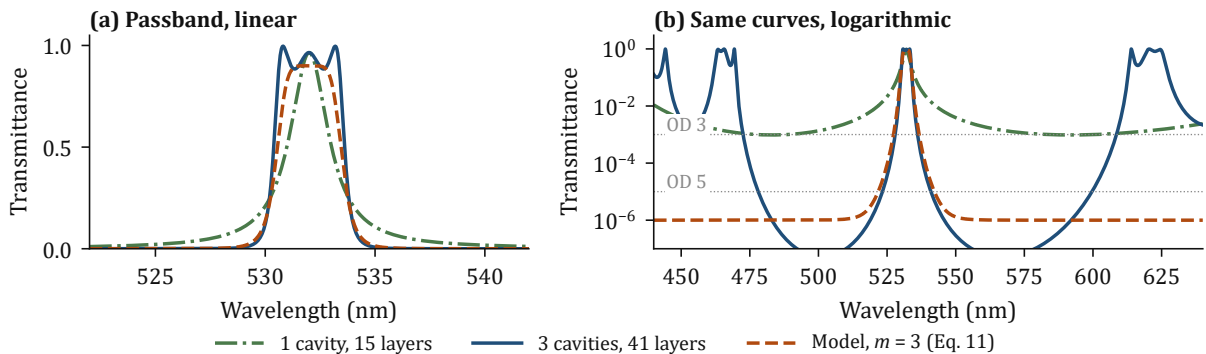


Figure 7. Three passbands centered at 532 nm, linear (a) and logarithmic (b). Dash-dot: a single cavity, 15 layers, FWHM 2.11 nm (air | (HL)³ H 2L H (LH)³ | fused silica, H 2.668, L 1.461). Solid: the three-cavity design, FWHM 3.23 nm (its mirrors only). Dashed: Eq. 11, FWHM 3 nm.

Bandwidth has to be specified for the beam the filter sees. A cone smears the passband because each ray sees its own center wavelength: in the f/2 beam tilted 10° of section 4 the 3 nm passband becomes a curve with a FWHM of

7.5 nm and a peak of 38.6 %, and a 10 nm passband becomes 11.4 nm at 80.7 %. A first budget for covering the whole cone is the spread (11.15 nm) plus the CWL tolerance range (2.0 nm) plus the temperature shift (0.19 nm), 13.3 nm in all. Wider is not free: for a flat background the power reaching the detector grows in proportion to the FWHM, so take the narrowest passband the budget allows.

6. Substrates, coatings and environment

Temperature. The passband moves to longer wavelengths as the filter warms, linearly over the specified range:

$$\text{CWL}(T) = \text{CWL}_{23} + k_T (T - 23^\circ\text{C}) \quad (12)$$

At 4 pm/K, 23 to 70 °C moves the center by 0.188 nm, which is 6 % of a 3 nm bandwidth, and -20 to +70 °C by 0.360 nm. At the 6 pm/K maximum, 23 to 70 °C gives 0.282 nm, and cooling a typical part to -20 °C gives -0.172 nm (Figure 8). It adds to the angle shift and is small beside it.

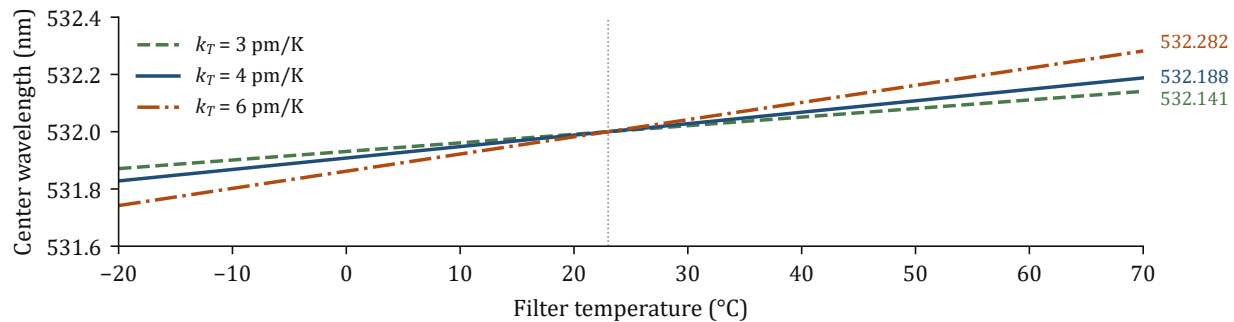


Figure 8. Center wavelength against filter temperature from Eq. 12 for temperature coefficients of 3, 4 and 6 pm/K (the family's typical and maximum values are 4 and 6 pm/K). End values are at 70 °C. The CWL tolerance of ± 1 nm applies at 23 °C and lies outside the plotted range.

Coating. Dense sputtered oxide coatings, such as the ion-beam-sputtered Nb_2O_5 and SiO_2 multilayer of the example family, are hard and change little with humidity. Porous evaporated films take up water, which raises their index and moves the passband to longer wavelengths (Macleod, ch. 13 and 14 [1]). Ask for the humidity result with its conditions: here, no measurable CWL shift after 24 h at 60 °C and 85 % relative humidity, on a lot sample. The rear face should be antireflection coated across the passband (here R under 0.5 % average, 400 to 1100 nm): an uncoated fused-silica surface reflects 3.5 %, which costs peak transmission and creates a second reflected beam.

Substrate. Fused silica expands 0.52 ppm/K (5 to 35 °C [9]) against 7.1 ppm/K for N-BK7 (-30 to +70 °C [8]), a factor of 13.7, which matters for coating stress and mounting. N-BK7 also absorbs in the ultraviolet: its internal transmittance over 10 mm is 0.967 at 350 nm, 0.77 at 320 nm and 0.29 at 300 nm [8], while standard-grade fused silica is certified for at least 80 % external transmission per centimeter at 185 nm [9]. Choose fused silica below about 350 nm and over wide temperature ranges.

Surface, wavefront and damage. Under MIL-PRF-13830B [5] the dig number of 60-40 is a diameter in hundredths of a millimeter, so 40 is 0.40 mm, while the scratch number is matched by eye to a comparison standard and is not a width; ISO 10110-7 [6] specifies imperfections by the area they affect or by visibility instead, so name the standard. A wavefront of $\lambda/4$ at 633 nm is 158 nm peak to valley. A 3 arcmin wedge in fused silica deviates a beam by $(n - 1)$ times the wedge, 1.38 arcmin or 0.40 mm per meter. A damage threshold holds only for the wavelength, pulse length, rate and spot size it was measured at (ISO 21254-1 [7]): 0.5 J/cm² in 10 ns is an average irradiance of 50 MW/cm², and a 500 mW continuous beam of 2 mm diameter is 15.9 W/cm², 63 times below the 1 kW/cm² CW figure. Mount the filter with the arrow in the direction of transmission and the coated face toward the source.

7. A selection flow

Figure 9 is the whole method on one page. The numbered procedure below is the same flow in words.

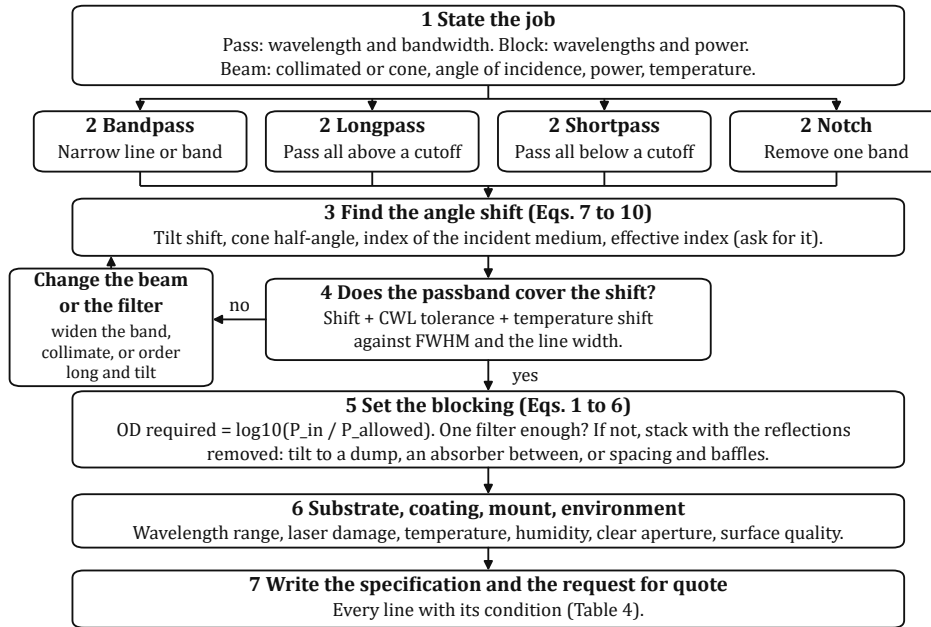


Figure 9. The selection flow, drawn from a layout script. Step 4 loops back until the passband covers the shift; equation numbers refer to sections 3 to 5.

1. State the job: the wavelength to pass and its width, the wavelengths to block and the power at each, and the beam (collimated or a cone, the angle, the polarization).
2. Pick the type from Table 1. A laser line with nothing else nearby is a bandpass; a laser line to remove from a spectrum is a notch or a longpass.
3. Compute the angle shift with Eqs. 7 to 10 for the real tilt and cone, using the effective index the supplier states.
4. Compare the shift plus the CWL tolerance plus the temperature shift with the FWHM. If the passband does not cover it, widen the band, collimate the beam, or order long and tilt.
5. Compute the required OD (Eq. 5). If one filter cannot carry it, stack filters with the reflections removed (Eqs. 2 and 6), and design to the parallel OD (Eq. 4) unless the layout removes the reflections.
6. Fix substrate, coating, mount, damage threshold and environment (section 6).
7. Write the specification with every condition (Table 4).

8. Worked examples

Each example uses the equations above with the numbers from `calc/examples.py`.

8.1 A 532 nm channel with 500 mW of leaked 1064 nm light

A frequency-doubled laser puts 500 mW of residual 1064 nm light through the same aperture as its 532 nm output, and the detector tolerates 1 nW at 1064 nm. 1064 nm lies inside the 400 to 1100 nm blocking range of NB-532-3-B, which guarantees OD 5. The requirement is OD 8.70 (Eq. 5). Two filters mounted parallel give OD 5.30, a margin of -3.40 and 2.50×10^3 nW: the budget fails by 3.40 decades. With the reflections removed the pair gives OD 10.00 and passes 0.0500 nW. Tilt the first filter by 5° : the reflected beam leaves at 10° , twice the tilt, and goes to a dump (Figure 3b). The price is the angle shift of Eq. 7: the center moves to 531.49 nm (-0.51 nm), and a nominal part still passes 89.9 % of the 532 nm line. A part at the 531 nm lower CWL limit would pass only 44.6 %, so order the tilted filter from units measured at 532.0 nm or longer, or use an absorber between untilted filters (Figure 3c).

8.2 The same filter in an $f/2$ cone at 10°

Section 4 gave a spread of 11.15 nm and a mean shift of -3.93 nm for this beam. Table 3 turns that into transmission of a 532 nm line. The 3 nm filter passes 25 % where a collimated, untilted beam would give 90 %. A 10 nm filter passes 59 %, and 80 % if it is ordered at 535.96 nm, the wavelength that puts the pupil mean on the line (532 nm times

532 nm over the mean of 528.07 nm); centering the smeared passband's half-maximum midpoint instead, as the companion article does, gives 535.32 nm and almost the same transmission. The 3 nm filter gains almost nothing from reordering, because its passband is narrower than the cone. Specify a FWHM of at least 10 nm and the CWL for the cone, or move the filter to collimated space.

Table 3. Transmission of a 532 nm line by the example passband (peak 90 %) at 10° tilt, from the model of Eq. 11 with the angle shift of Eq. 7, averaged over the pupil in the cone.

Case	FWHM 3 nm	FWHM 10 nm
Collimated beam, CWL ordered 532 nm	13.3 %	89.6 %
f/2 cone, CWL ordered 532 nm	25.4 %	59.5 %
f/2 cone, CWL ordered 535.96 nm	28.0 %	80.4 %

8.3 Order long and tilt

A line source at 530.0 nm needs a filter centered there, and the 532 nm part can be tuned to it. Eq. 8 gives a tilt of 9.98° for n_{eff} 2.0, and Eq. 7 returns 530.0 nm. At that angle the center moves 0.398 nm per degree, so holding it within ± 0.2 nm takes a tilt within $\pm 0.50^\circ$; the family's effective-index range of 1.9 to 2.1 alone spans 9.47° to 10.48°, so tune the tilt on the transmitted line. Check the cone budget as well: keeping the spread across the beam under 0.5 nm, a sixth of the FWHM, needs a working f-number above 45.6, a half-angle under 0.63° (11.0 mrad). At f/10 the spread is 2.27 nm and at f/20 it is 1.14 nm. A collimated laser beam fits; a focused beam does not.

9. Request-for-quote checklist

Table 4 is the list to send. A supplier that cannot fill a line has told you something.

Table 4. Request-for-quote checklist: send every line with its condition. The last column is the example filled in.

Item	Include	Example
Part and quantity	Part number or family key, quantity, delivery date	NB-532-3-B, quantity and date
Center wavelength	Value, tolerance, definition, AOI, temperature, polarization	532 $\pm$ 1 nm, midpoint of half-maximum points, AOI 0°, 23 °C, unpolarized
Bandwidth	FWHM, min and max, same conditions	3.0 nm (2.6 to 3.4)
Peak transmission	Minimum, at which wavelength	85 % at the measured CWL
Blocking	OD, range, exclusion zone, the wavelength that matters and its power	OD 5, 400 to 1100 nm outside CWL $\pm$ 12 nm; 500 mW at 1064 nm
Beam and layout	Collimated or f-number, diameter, angle, polarization, power; number of filters, parallel, tilted or with an absorber	Collimated, 2 mm; two filters, one tilted 5°
Effective index	Range, fitted angles, curves measured at the angle used	2.0 (1.9 to 2.1), 10° and 20°
Temperature	Operating range and CWL coefficient	-20 to +70 °C; +6 pm/K max
Substrate and size	Material, thickness, diameter, clear aperture, mount, coated face	UV fused silica, 2.0 mm; 25.0 mm; CA 21.0 mm
Surface and wavefront	Scratch-dig with its standard, wavefront with its wavelength, wedge	60-40 (MIL-PRF-13830B); $\lambda/4$ at 633 nm; under 3 arcmin
Damage threshold	Wavelength, pulse length, rate, spot size, or CW	0.5 J/cm ² , 532 nm, 10 ns, 20 Hz
Environment	Humidity and temperature tests with their conditions	24 h at 60 °C, 85 % RH, lot sample
Data with delivery	Which quantities are measured on every unit, the instrument limit	CWL, FWHM, peak on every unit; blocking on a lot; OD limit 6.5

Notes

Symbols. λ_0 center wavelength at normal incidence; $\lambda(\theta)$ center wavelength at angle θ ; θ_t tilt to a target λ_t ; n_0 index of the incident medium; n_{eff} effective index; α cone half-angle; N working f-number; OD optical density, $-\log_{10} T$; T , R transmittance and reflectance; ρ share of blocked light reflected; D loss denominator of Eqs. 3 and 4; P power; M margin; k_T temperature coefficient of the center wavelength; m passband order of Eq. 11.

Method and limits. The stack calculation treats each filter as one element with one transmittance and reflectance, the same from both sides, adds reflections between parallel filters incoherently, and ignores scatter, other surfaces, the change of OD with angle and light that goes around the filters. The tilt model is the single effective index: good at small and moderate angles for one polarization, approximate where s and p separate. The cone results assume a uniformly filled circular pupil and a fixed bandwidth. Figures 6 and 7 come from a transfer-matrix calculation (real, non-dispersive indices) of a representative design that illustrates behavior; it is not a production coating. Eq. 11 models a typical curve. These are estimates for early design: confirm them against the supplier's measured curves and by measurement in your system.

Calculators. Eqs. 1 to 6 are implemented at <https://jezdangomez.com/calculators/optical-density-stack/> [3] and Eqs. 7 to 10 at <https://jezdangomez.com/calculators/aoi-shift/> [4], with the defaults used in this guide. The calculation files, figure scripts and numeric audit that regenerate every number here accompany the document.

Sepe Optics is a fictional company. Portfolio sample by Jezdan Gomez, jezdangomez.com.

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