

Band Pass Filters, Low Pass Filters and Dichroic Beamsplitters for the entire Infrared and THz Region.

I. Band Pass Filters

The filters are constructed as free standing electroformed metal screens. Design and manufacturing of filters with desired Peak Wavelength (PW) and Width of Band (WoB), using various materials.

The Filters have:

High peak transmittance and no fringes on account of absence of a dielectric substrate.

Elimination of short wavelength radiation:

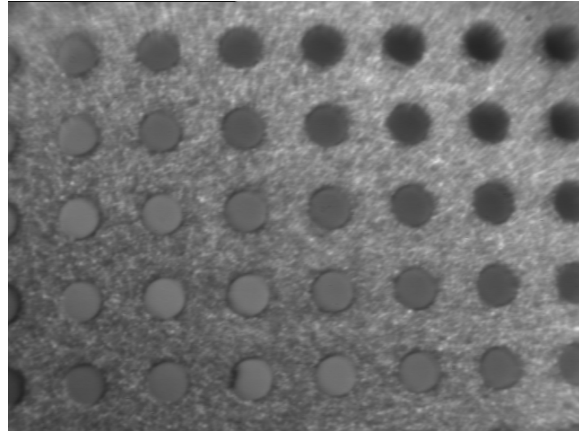
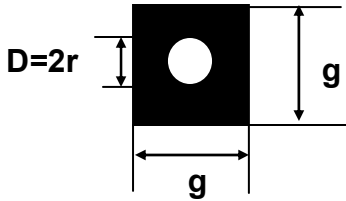
Two or three filters eliminate all short wavelength radiation when using black body sources or synchrotrons.

- 1. Rectangular Screens with Round Hole Openings.**
- 2. Rectangular Screens with Cross shaped Openings.**
- 3. Rectangular Screens with Square shaped Openings.**
- 4. Hexagonal Screens with Hexagonal Openings.**

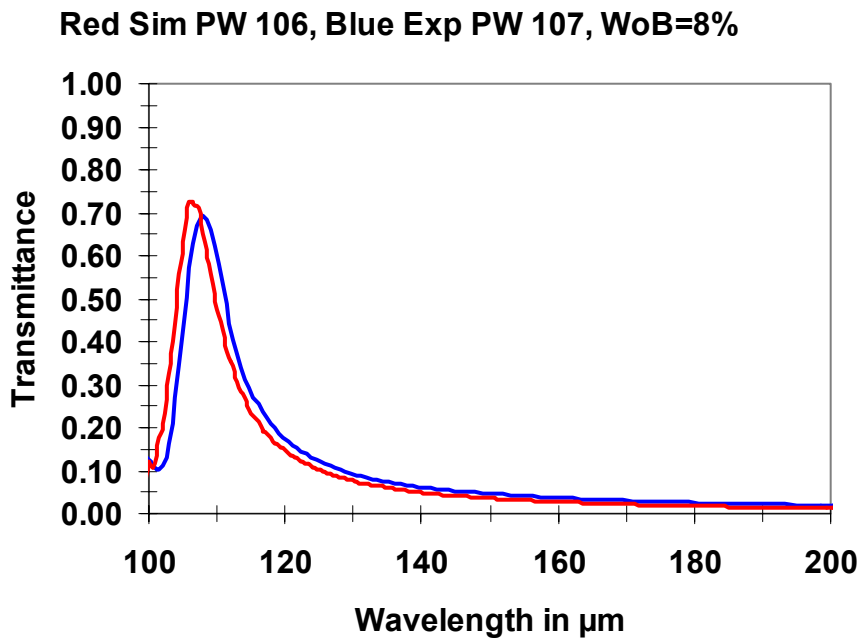
1. Rectangular Screens with Round Hole Openings.

1.A. Free standing metal screens with round holes, $g = 100 \mu\text{m}$, $D=50 \mu\text{m}$, Thickness $t= 5 \mu\text{m}$.

Periodicity constant g
Hole Diameter $D=2r$
Thickness t

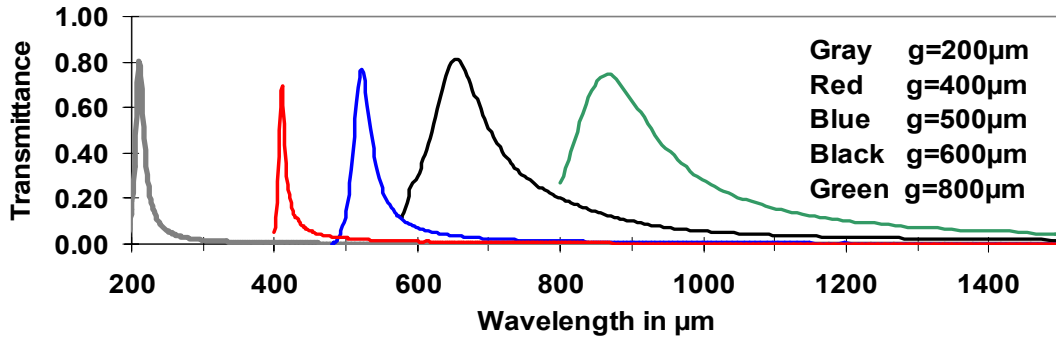


Demonstration of excellent agreement of Micro-Stripes Simulations and Experimental Measurements.



Nickel Screen of $g = 100\mu\text{m}$, $D=50 \mu\text{m}$, Thickness $t= 5 \mu\text{m}$

1.B. Peak Wavelength over large Spectral Range and Empirical Formula.



The periodicity constant g is the dominating parameter for the determination of the peak wavelength.

Empirical Formula

For fixed thickness of about $4\mu\text{m}$, the peak wavelength is given as

$$\lambda_p = 0.9g + 0.22D$$

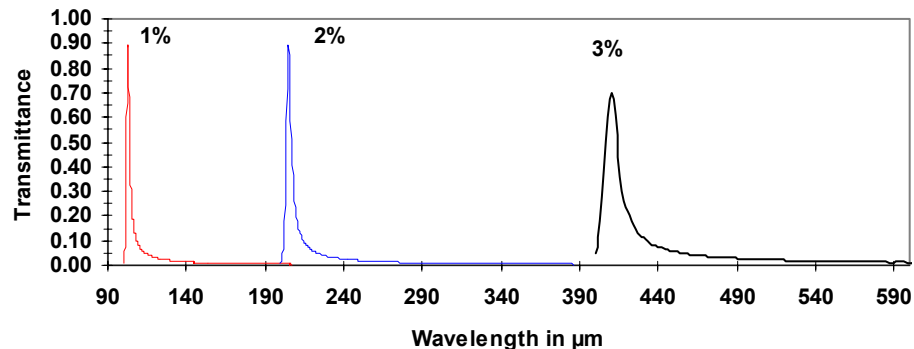
The formula may be used to determine starting parameters for a Micro-Stripes Simulation to determine parameters of a screen with desired peak (PW) and (WoB)

1.C. Simulations of Narrow Width of Band (WoB) Filters for a large Spectral Region.

(WoB) is calculated as ratio of width at half height, divided by (PW)

The transmitted Intensity and (WoB) are effected by the thickness. For fixed periodicity constant g and opening diameter D , the (WoB) and the Intensity are reduced with enlarged thicknesses.

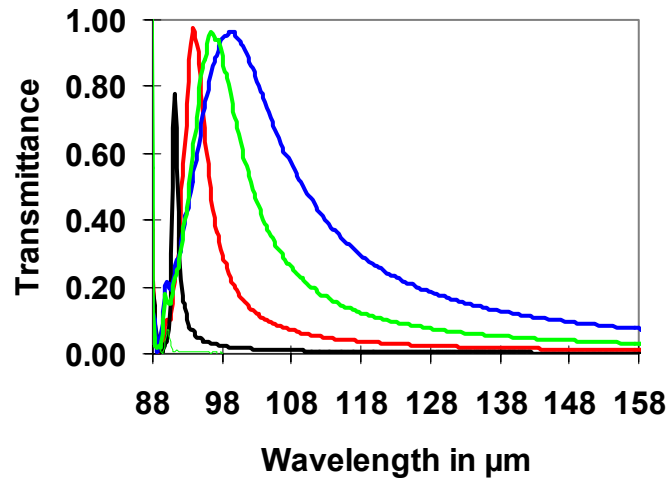
1.C.a. Narrow Band Pass Filters of WoB 1%, 2%, and 3%



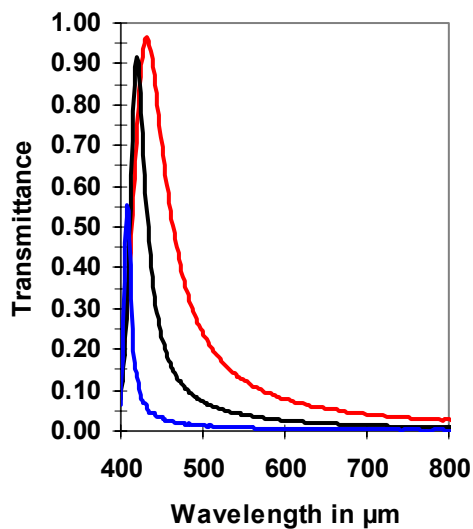
Ratio of opening diameter to periodicity constant: $D/g=0.2$, for all three.

Aluminum, thickness $2\mu\text{m}$ for $100\mu\text{m}$ (3THz), $5\mu\text{m}$ for at $200\mu\text{m}$ (1.5THz) and $400\mu\text{m}$ (750GHz).

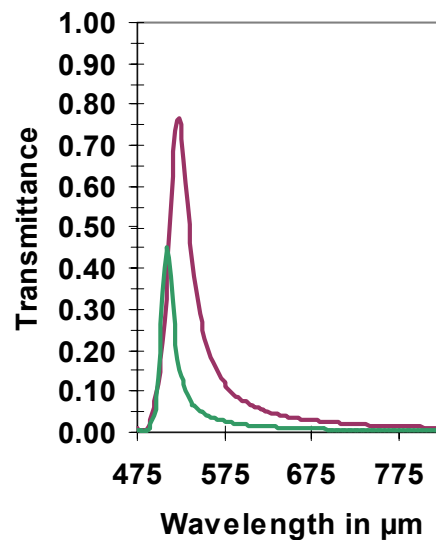
1.C.b. Dependence on Periodicity Constant g .



Fixed $t=4 \mu\text{m}$
 Fixed Opening Diameter $D=54 \mu\text{m}$
 Periodicity constants g
 Blue 90, Green 95, Red 100, Black 105 (in μm).



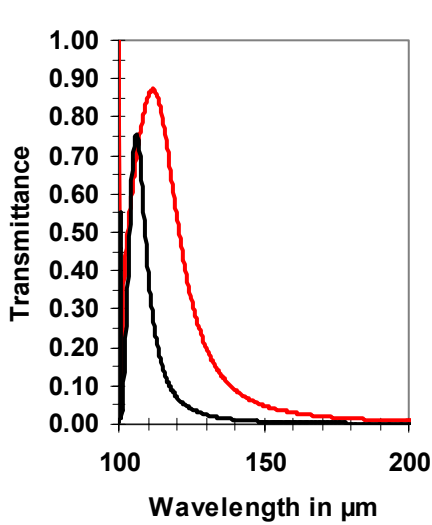
Fixed $t=33 \mu\text{m}$
 Fixed Opening Diameter $D=200 \mu\text{m}$
 Periodicity constants g
 Red 425, Black 400, Blue 375 (in μm).



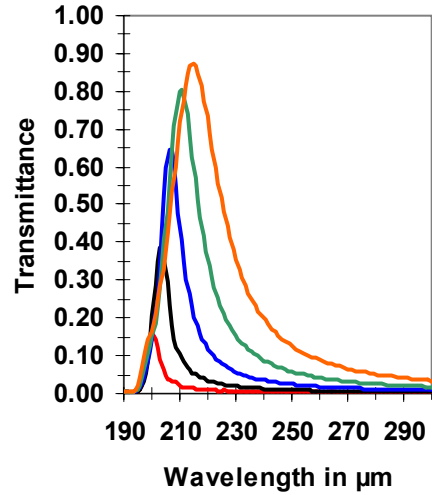
Fixed $D=254 \mu\text{m}$, fixed $t=50 \mu\text{m}$
 Periodicity constant g
 Brown $500 \mu\text{m}$, Green $525 \mu\text{m}$

1.C.c. Dependence on Opening diameter D.

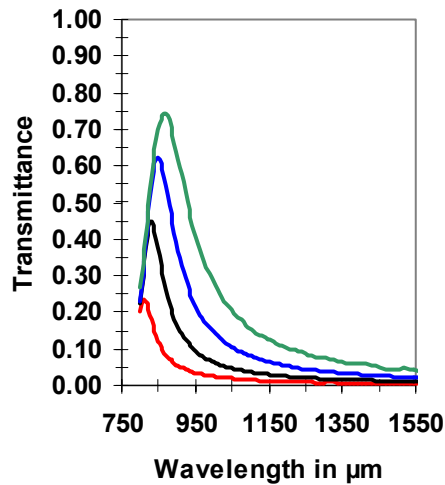
Simulations for (PW) and (WoB) depending on Openings Diameter D, for fixed g and t. The Intensity is reduced with reduced value of (D/g)



Fixed Periodicity constants $g=100\mu\text{m}$
 Fixed $t=33\mu\text{m}$
 Opening Diameter
 Red 68. Black 58 (in μm).

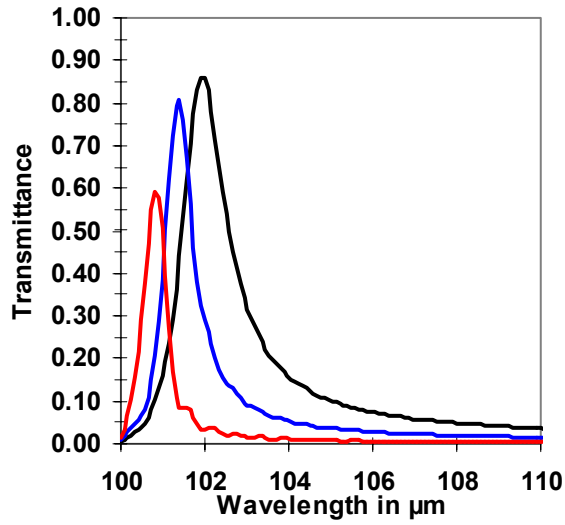


Fixed Periodicity constants $g=200\mu\text{m}$
 Fixed $t=25\mu\text{m}$
 Opening Diameter
 Yellow 112, Green 104, Blue 96,
 Black 88, Red 80 (in μm)

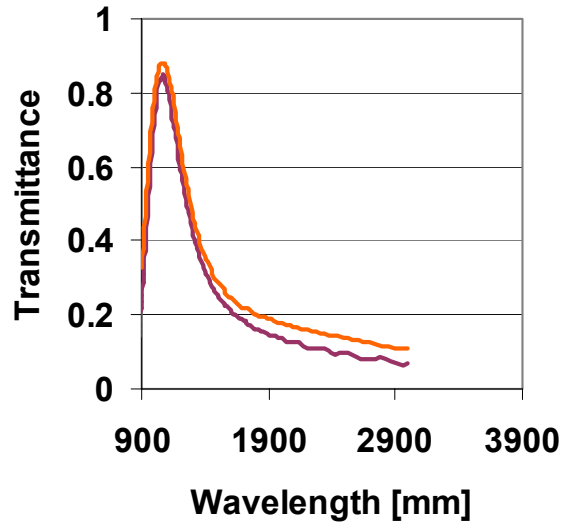


Fixed Periodicity constants $g=800\mu\text{m}$
 Fixed $t=25\mu\text{m}$
 Opening Diameter
 Green 460, Blue 420, Black 380, Red 340 (in μm)

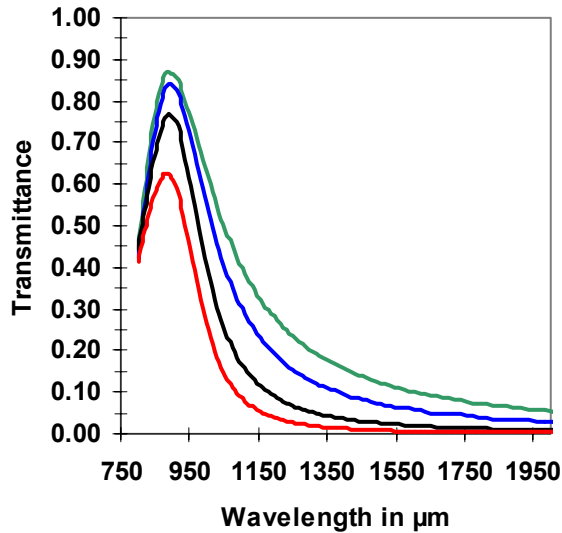
1.C.d. Dependence on Thickness



Fixed Periodicity constants $g=100\mu\text{m}$
 Fixed Opening Diameter $D=40\mu\text{m}$
 Thickness
 Black 5, Blue 10, Red 20 (in μm)



Fixed Periodicity constant $g=900\mu\text{m}$
 Fixed Opening Diameter $D=686\mu\text{m}$
 Thickness
 Orange 25, Brown 40 (in μm)

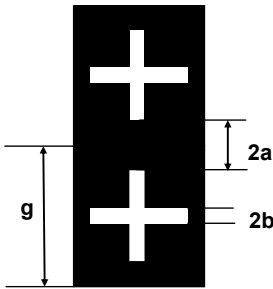


Fixed Periodicity constants $g=800\mu\text{m}$
 Fixed Opening Diameter $D=560\mu\text{m}$
 Thickness
 Green 50, Blue 100, Black 200, Red 300 (in μm)

2. Rectangular Screens with Cross shaped Openings.

2. A. Cross shaped Screen with $g=17\ \mu\text{m}$, $2a=6\ \mu\text{m}$, $2b=5.2\ \mu\text{m}$ and thickness $3\ \mu\text{m}$.

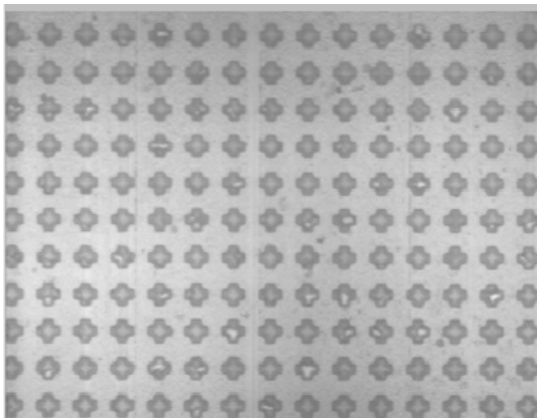
Geometrical Parameters



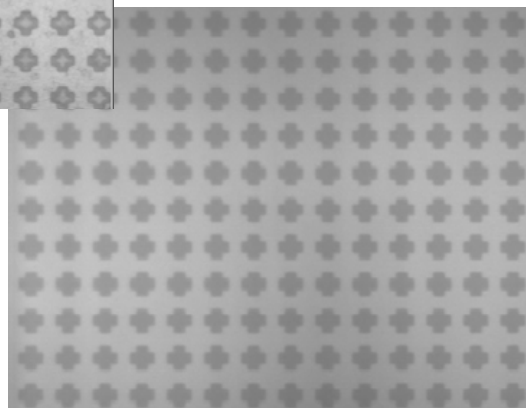
Periodicity constant g ,
Distance between crosses $2a$,
width of cross arm $2b$.

Mask and electroformed Screen

Sample parameters
 $g=17\ \mu\text{m}$, $2a=6\ \mu\text{m}$, $2b=5.2\ \mu\text{m}$
and thickness $3\ \mu\text{m}$

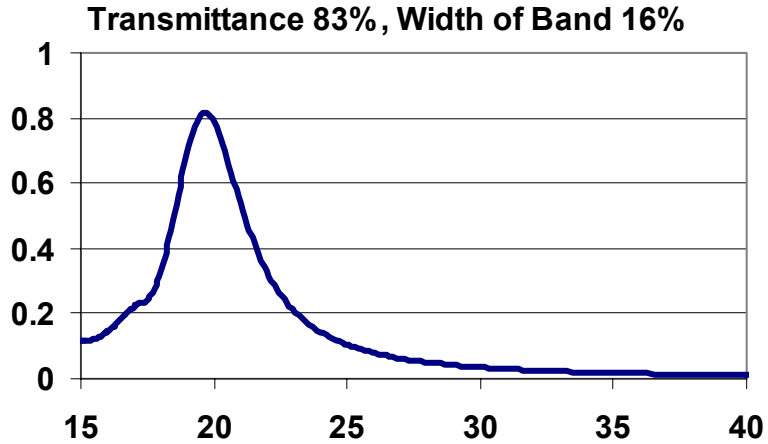


electroformed screen



Mask

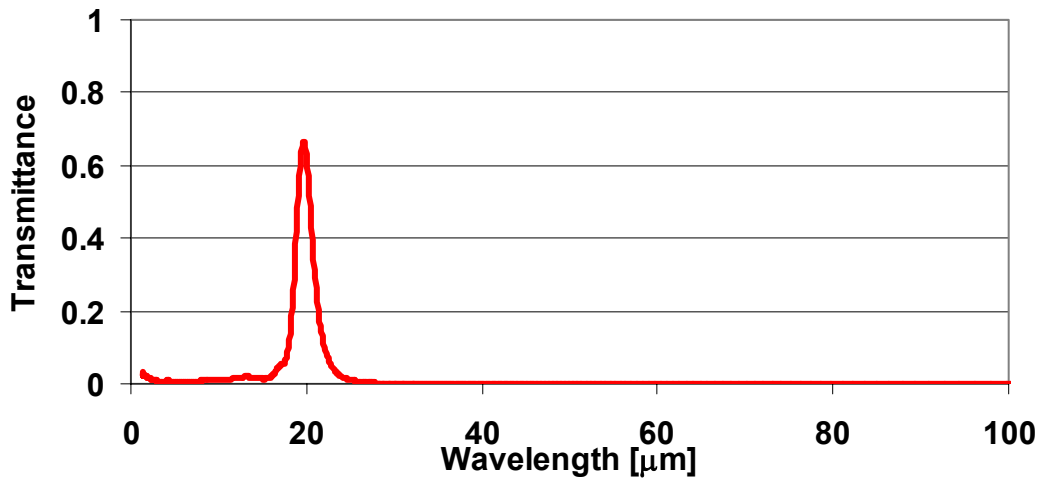
Transmittance



Experimental Fabrication of a free standing metal screen of Ni with periodicity constant $17 \mu\text{m}$ and thickness $3 \mu\text{m}$.

2.B. Two Filters for blocking off shorter and longer Wavelength.

Transmittance: 65% and (WoB): 10%.



Two free standing Ni screens at arbitrary distance, very good blocking of short and long wavelength radiation.

2. C. Empirical Formula:

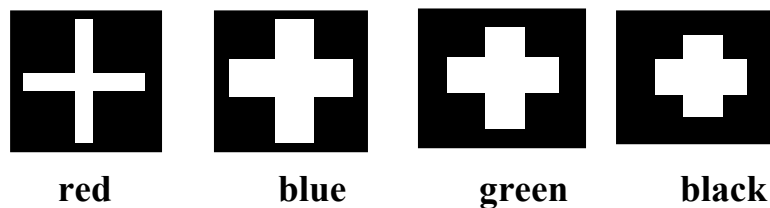
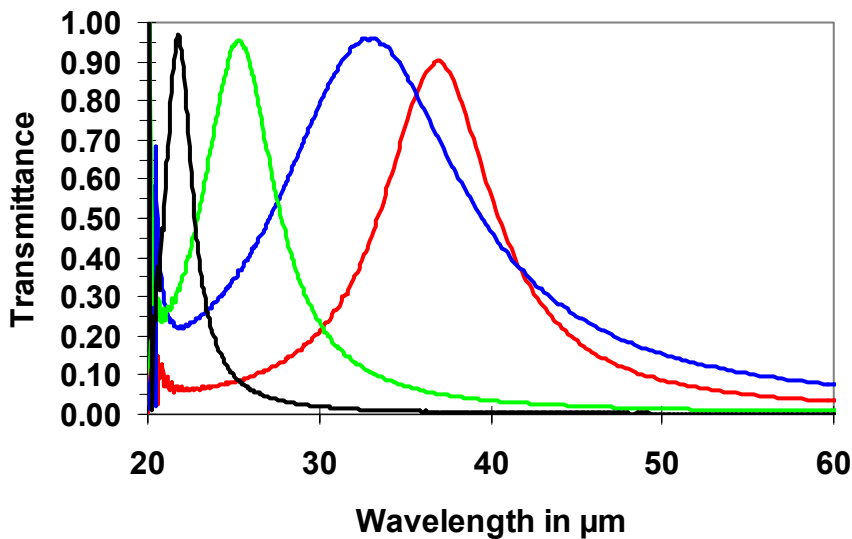
The empirical formula for (PW): $\lambda_p = 2g - 4a - 2b$

The formula may be used to determine starting parameters for a Micro-Stripes Simulation of a screen with a desired (PW) and (WoB).

More details:

K. D. Möller, J. B. Warren, J. B. Heaney, and C. Kotecki, "Cross-shaped bandpass filters for the near- and mid-infrared wavelength regions," *Appl. Opt.* **35**, 6210-6215 (1983).

2. D. Cross shaped screens in Cu with $g=20 \mu\text{m}$ and $t=4 \mu\text{m}$ thick for different cross sizes.



Screens with similar types of crosses have been studied experimentally by:

S. T. Chase and R. D. Joseph, "Resonant array bandpass filters for the far infrared," *Appl. Opt.* **22**, 1775-1779 (1983).

3. Rectangular Screen with Square shaped Openings.

There are Metal Screens available from Buckbee-Mears, St.Paul MN 55101, for a fixed number of periodicity constants, made of Cu or Ni of thickness $t=3$ to $5 \mu\text{m}$.

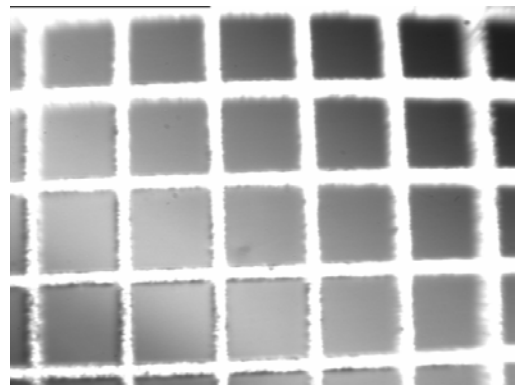
We can design, simulate and manufacture free standing square shaped Ni and Cu Screens for any (in limits) desired (PW) and (WOB) from $1 \mu\text{m}$ to the THz Region

3.A. Examples of Buckbee-Mears Screens

Some Square shaped metal screens available from Buckbee-Mears.

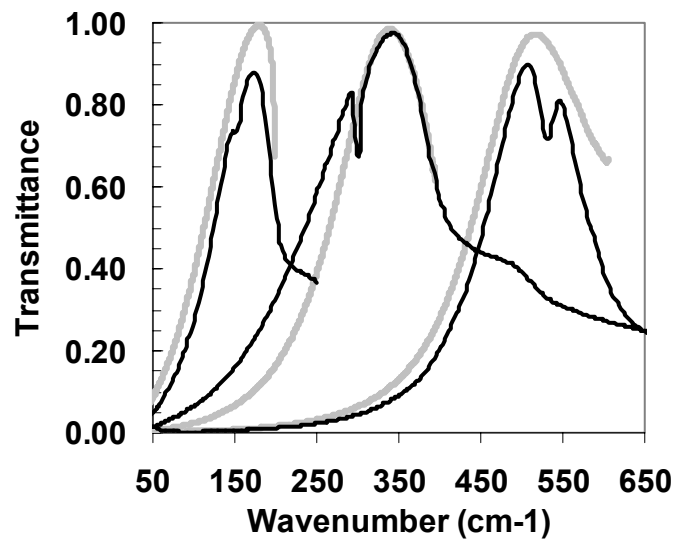
Specifications of some screens made by Buckbee and Mears

Mesh l/in	perod.con.		Thickness t
	g	d	
2000	12.7	7.5	4
1500	16.4	11.2	4
1000	25.4	18	4
500	51	40	4
400	63.5	49	4



Micro-Stripes Simulations.

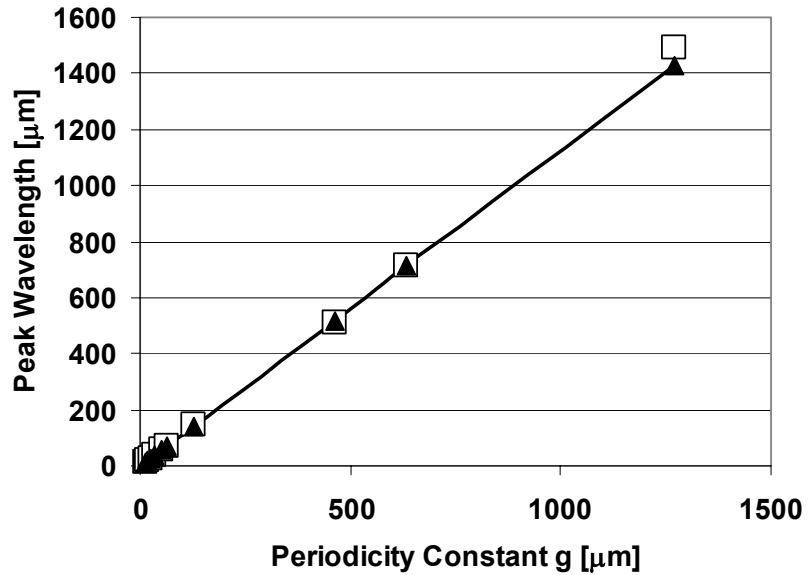
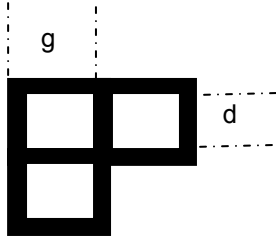
MS-Simulations and experimental results of screen with 500, 1000 and 1500 lines per inch, with peak wavelength at about $160\mu\text{m}$ (500), $350\mu\text{m}$ (1000) and $540 \mu\text{m}$ (1500).



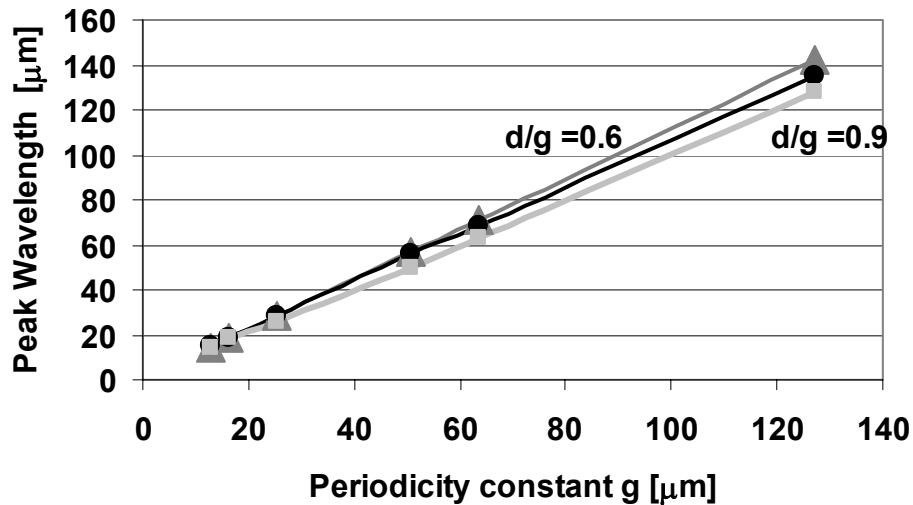
3.B. Empirical Formula

(PW): $\lambda_R = 0.75g + 0.5d$ for $d/g = 0.75$

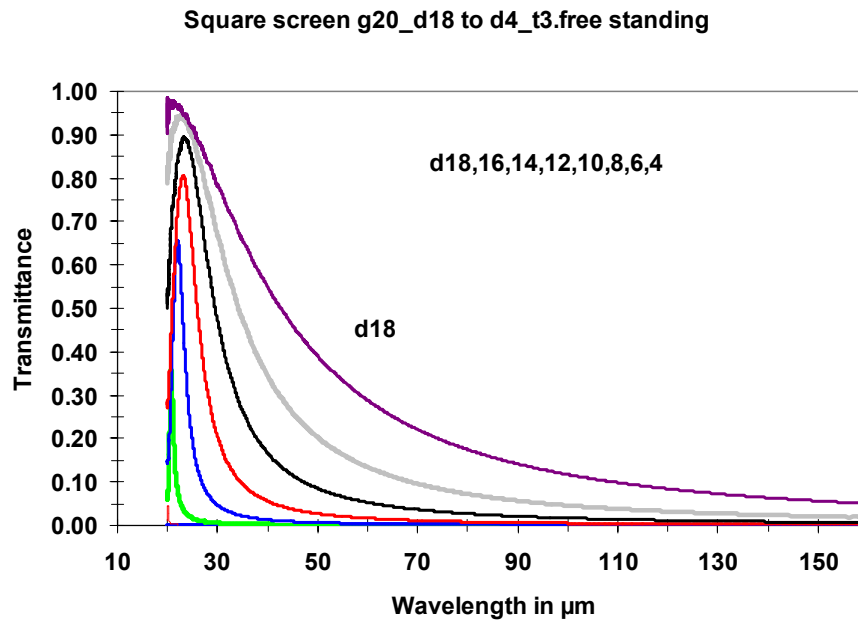
The formula may be used to determine starting parameters for a Micro-Stripes Simulation of a screen with a desired peak wavelength and width of band.



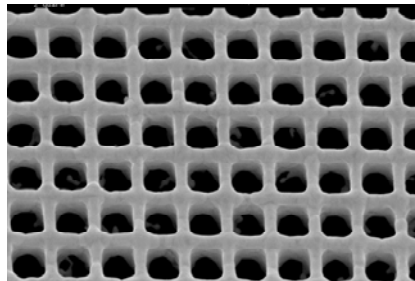
Simulations for $d/g = 0.6, 0.75, 0.9$



3.C. Dependence on diameter of opening d for fixed periodicity constant g and thickness t .



3.D. Thick Nickel Screen with opening Length $d = 1 \mu\text{m}$ Free standing Nickel Screens, $2.3 \mu\text{m}$ thick, with opening lengths $d = 1 \mu\text{m}$ and periodicity constant of $1.3 \mu\text{m}$



The properties of this screen have been studied and are given in:

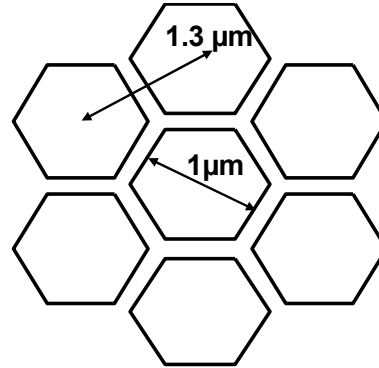
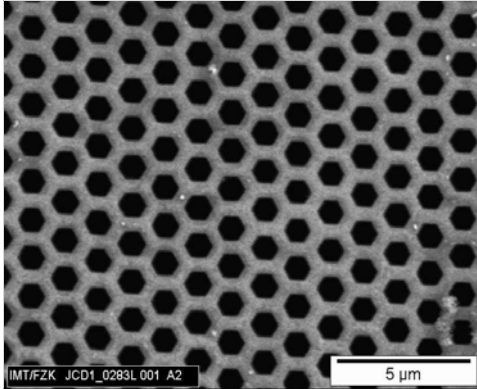
Band pass filters in the $1 \mu\text{m}$ spectral region: Thick metal screens

Infrared Physics & Technology, Volume 51, Issue 3, January 2008, Pages 178-185

A. Lüker, H. Hein, J. Schulz, N. Dambrowsky, O. Sternberg, M.J. Sweetgall, K. Abdijalilov, K.D. Möller and H. Grebel

4. Thick Hexagonal screens with Hexagonal Openings.

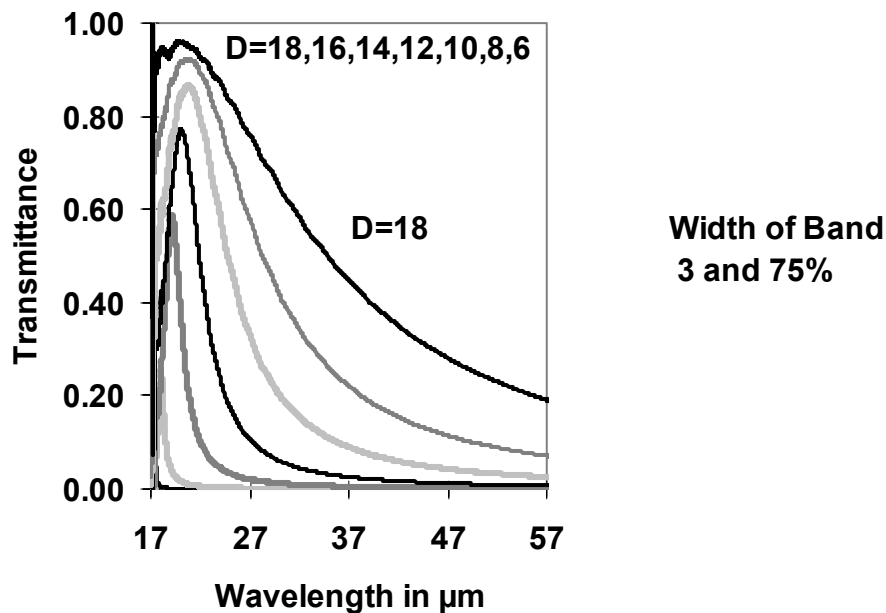
4.A. Free standing Nickel Screens, 2.3 μm thick, of hexagonal structure, with opening lengths $D = 1 \mu\text{m}$ and periodicity constant of 1.3 μm



Empirical formula: $\lambda_p = 0.9g + 0.22D$, where g is the periodicity constant and D the opening diameter

The formula may be used to determine starting parameters for a Micro-Stripes Simulation of a screen with a desired peak wavelength and width of band.

4.B. Dependence on opening diameters D for fixed



More Details

Infrared Physics & Technology, Volume 51, Issue 3, January 2008, Pages 178-185

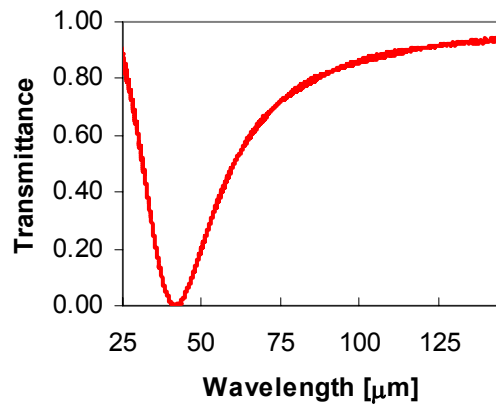
A. Lüker, H. Hein, J. Schulz, N. Dambrowsky, O. Sternberg, M.J. Sweetgall, K. Abdijalilov, K.D. Möller and H. Grebel

II. Low Pass Filters and Dichroic Beam Splitters

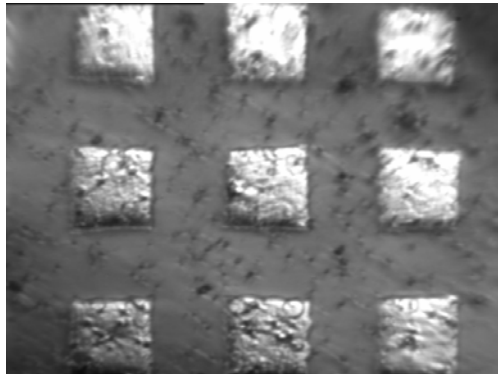
1. Capacitive Screens

Capacitive screens have a complementary structure of Inductive screens, and have as well complementary transmittance.

The (PW) of an inductive screen and the Dip Wavelength (DP) of the capacitive screen have the same value.



Capacitive screens are made of metal islands on a substrate.

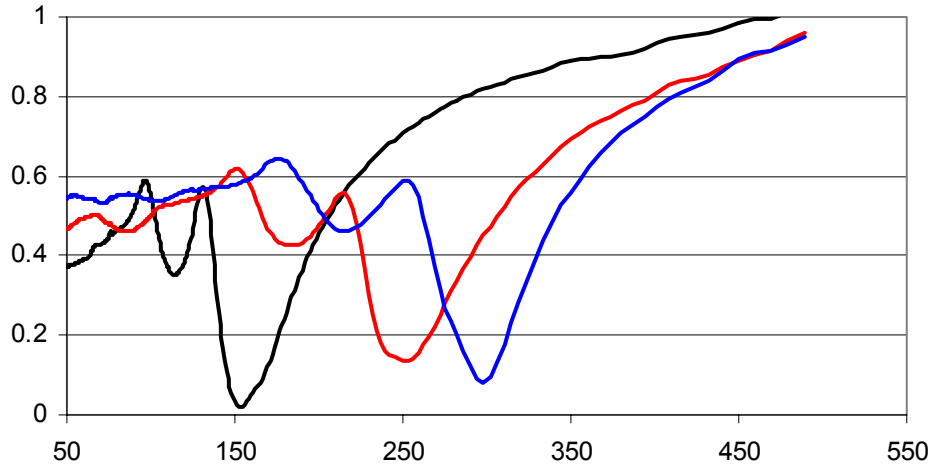


Capacitive Screen with metal rectangles on a Mylar substrate of thickness 2.5μm

Empirical Formula:

The (DW) can be obtained approximately similar to the (PW) of the complementary inductive screen: $\lambda_D 1.2g$.

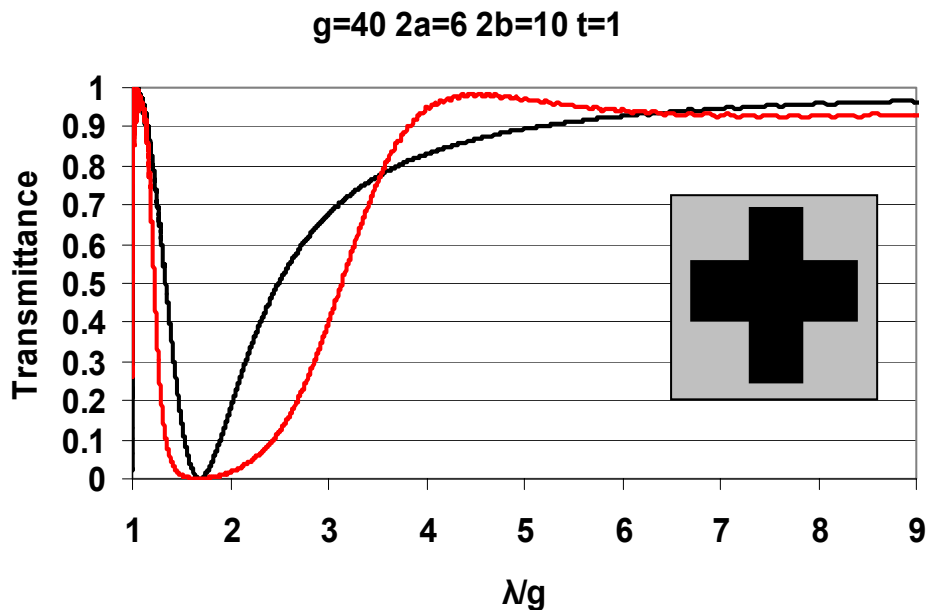
Transmittance of capacitive screens of rectangular structure with periodicity constants g and Dip Wavelength λ_D : Blue $g = 254 \mu\text{m}$, $\lambda_D = 297 \mu\text{m}$, Red $g = 211 \mu\text{m}$, $\lambda_D = 253 \mu\text{m}$, Black $g = 127 \mu\text{m}$, $\lambda_D = 155 \mu\text{m}$

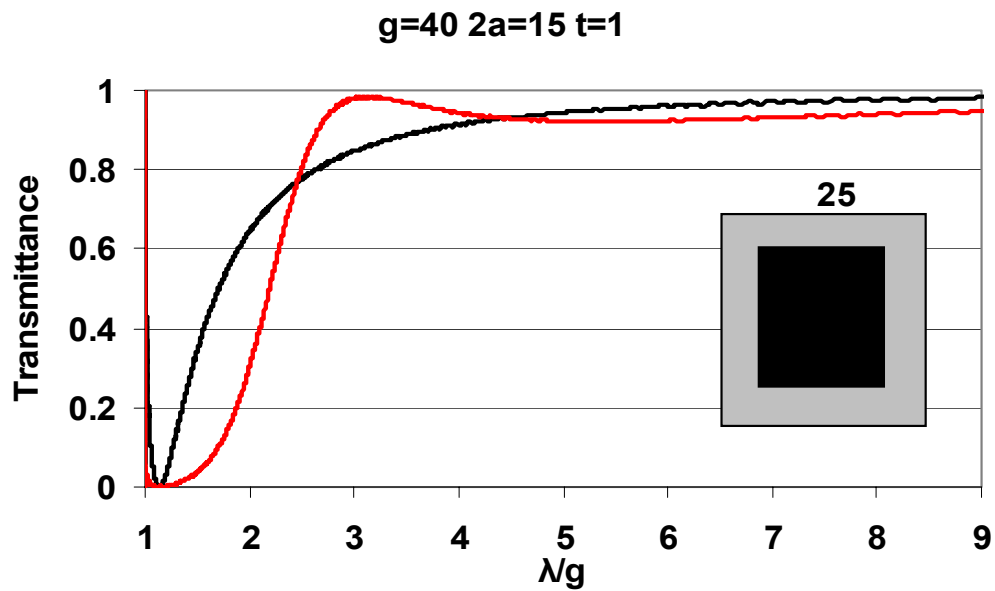
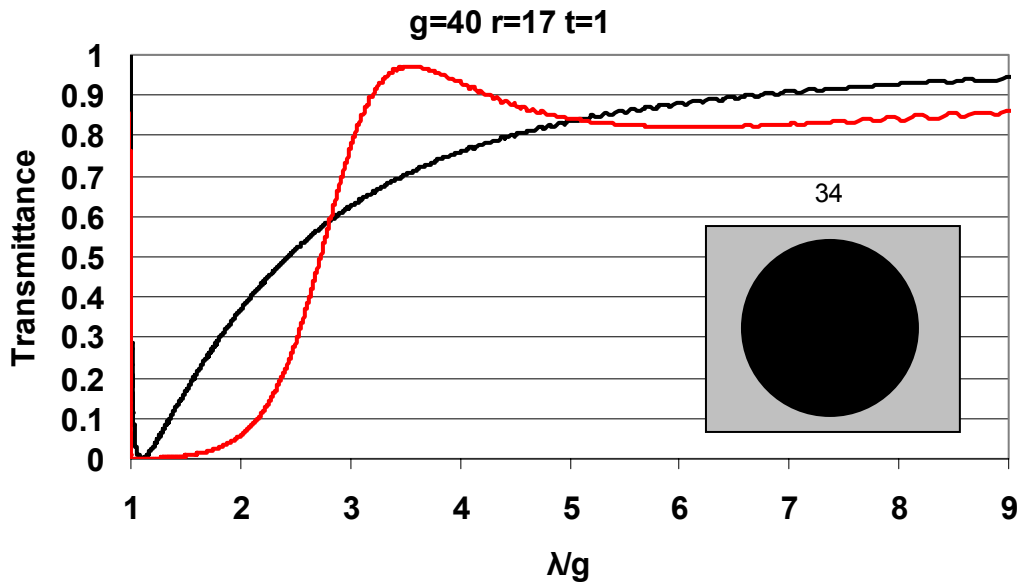


2. Simulation of Dichroic Beamsplitters at Normal Incidence.

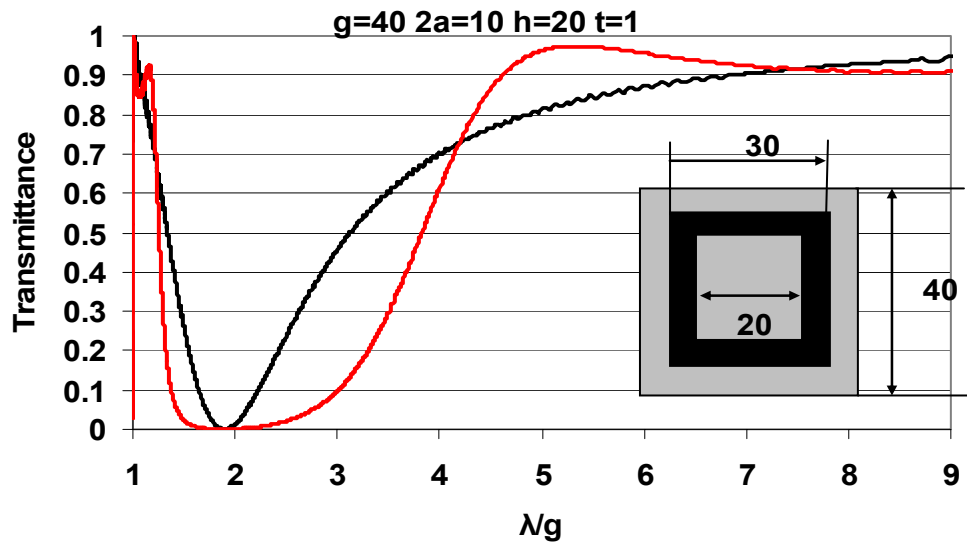
A dichroic beamsplitter passes in reflection and transmission different ranges of wavelengths. Capacitive screens may be used for their construction.

Simulations of the transmittance of one (black) or two (red) screens of loop and cross shape are shown, and of particular interest is the slope dividing the spectrum to longer wavelength.





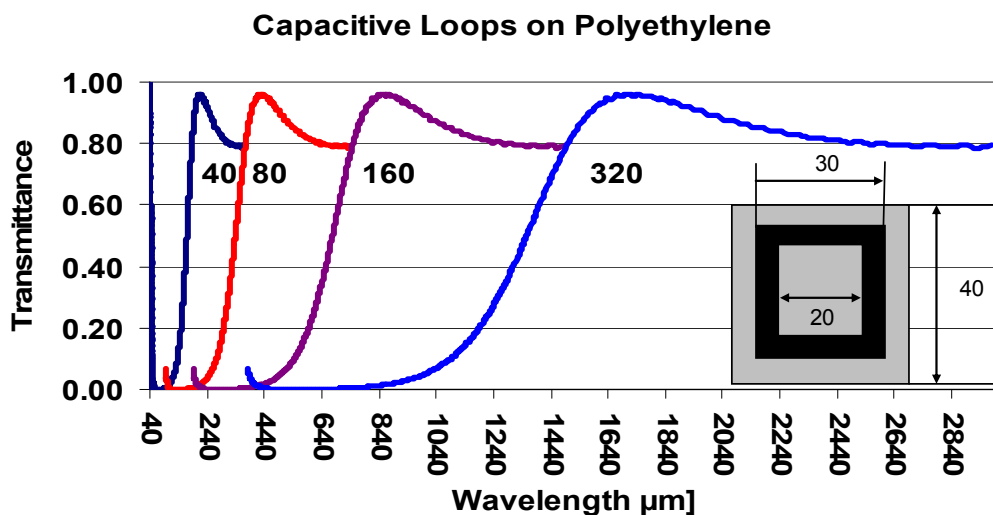
The width of the stop band, the slop and the peak transmittance at longer wavelength may be (in limits) varied by the choice of the structure of the islands of the capacitive metal screens.



The simulated transmittance is shown for two screens at normal incidence. However, the design of the optical instrumentation may require a dichroic beamsplitter to be used at incident angle of 45° . A study of the transmittance of capacitive screens at various angles of incidence is presently under way at the Electronic Imaging Laboratory, NJIT.

2. Low pass Filter.

We have plotted the transmittance of four loop mesh filters with periodicity constants 40, 80, 160 and 320 μm and the same ratio of the loop parameters to the periodicity constant



Blocking off spectral regions from 40 to 900 μm using 4 filters, each with blocking of one octave