ADAS414: Prepare soft X-ray filter file

The code generates a numerical representation of the characteristics of thin window filter/diode soft X-ray detectors used in measurements of radiant power from fusion plasmas.

Background theory:

Filter/diode detectors have been in general use in fusion for measurements of the radiated power from the high temperature plasma. The devices have a characteristic pass band in the soft X-ray region determined by the transmission of sub-micron deposited metallic layers on a thin window and the absorption in the semiconductor diode substrate. In ADAS modelling of the populations and ionisation state of impurities in plasmas, the radiant power (cf. *plt*, *prb*, *prc* dataset libraries) is an important output quantity. Also, recognising the nature of radiant power measurements, radiant power datasets modified by simple cut-off or Be/Si filter representations have been introduced (cf. ADAS408, ADAS208). These representations are now felt to be too crude for present work, especially if discrimination of the broad transition array features from different heavy metals is to be achieved. A better representation is sought. The spectral absorption characteristics of elements have been collected and tabulated by Henke et al. (1993). These data are maintained for internet access (*http://xray.uu.se*) and provide all necessary information for the present purpose. ADAS414 prepares a numerical representation of a filter/diode combination from Henke absorption data in a form suitable for subsequent ADAS use. The filter is created interactively with graphical display and the final output file may be used by the appropriate ADAS power codes.

Let the frequency dependent absorption cross-section of a thin layer of element **A**, at frequency ν be $a_\nu^{(A)}$ so that the intensity variation through the layer is given by

$$\frac{dI_\nu}{dl} = N^{(A)} a_\nu^{(A)} I_\nu \qquad 5.14.1$$

with $N^{(A)}$ is the number density of element **A** in the layer. Thus after passage through a set of elemental layers of thickness $d^{(A)}$

$$I_\nu = I_\nu(0)\exp(-\sum_A N^{(A)} a_\nu^{(A)} d^{(A)}) . \qquad 5.14.2$$

Thus the transmission, T_ν, through the multi-layer is

$$T_\nu = \exp(-\sum_A N^{(A)} a_\nu^{(A)} d^{(A)}) . \qquad 5.14.3$$

Setting $d = \sum_A d^{(A)}$ and $N = \sum_A N^{(A)} d^{(A)} / d$, the multi-layer-mean absorption cross-section is

$$a_\nu = \sum_A N^{(A)} a_\nu^{(A)} d^{(A)} / Nd . \qquad 5.14.4$$

In stead of the cross-section it is common to give the imaginary part of the forward scattering factor for a single element layer as

$$F_{2,\nu}^{A} = \nu a_\nu^{A} / 2 r_0 c \qquad 5.14.5$$

and the multi-layer mean imaginary part of the forward scattering factor as

$$F_{2,\nu} = \nu a_\nu / 2 r_0 c . \qquad 5.14.6$$

r_0 is the classical electron radius.

For a semiconductor substrate, of element denoted by B, of number density $N^{(B)}$ and thickness $D^{(B)}$, the absorption factor is $(1-\exp(-N^{(B)}a_v^{(B)}D^{(B)}))$ so that the final filter factor, F_v, is

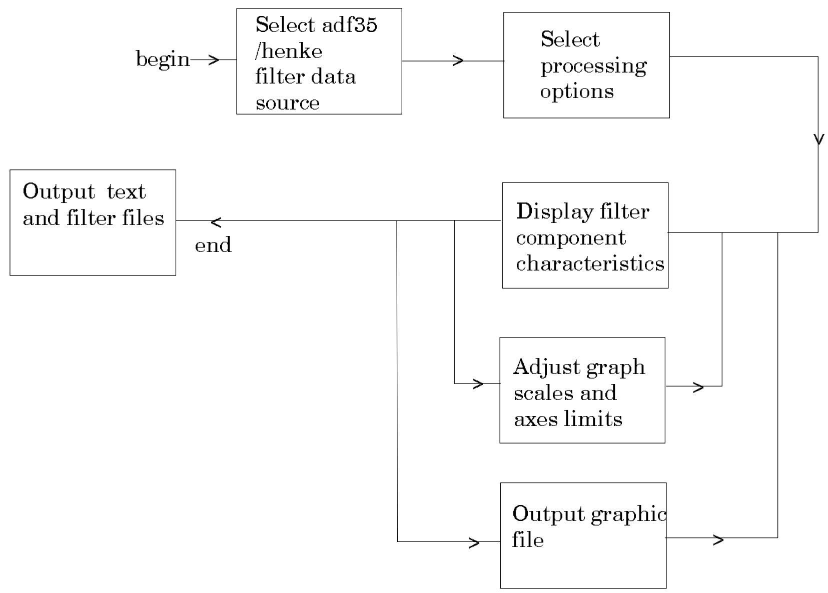
$$F_v = (1-\exp(-N^{(B)}a_v^{(B)}D^{(B)}))\exp(-\sum_A N^{(A)}a_v^{(A)}d^{(A)}) \qquad 5.14.7$$

[Ref. Henke, Gullikson & Davis (1993) At. Data and Nucl. Data Tables 54, no. 2]

Program steps:

These are summarised in figure 5.14.

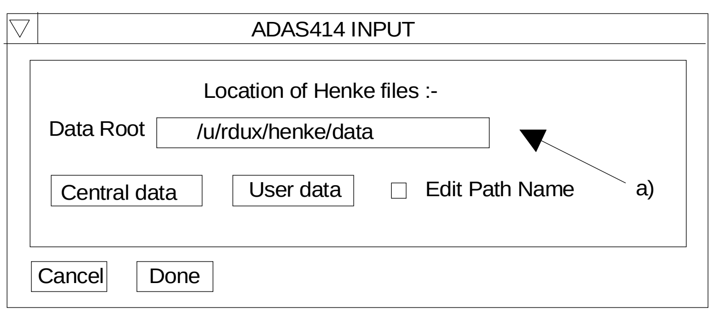
Figure 5.14



Interactive parameter comments:

The **file selection window** has the appearance shown below

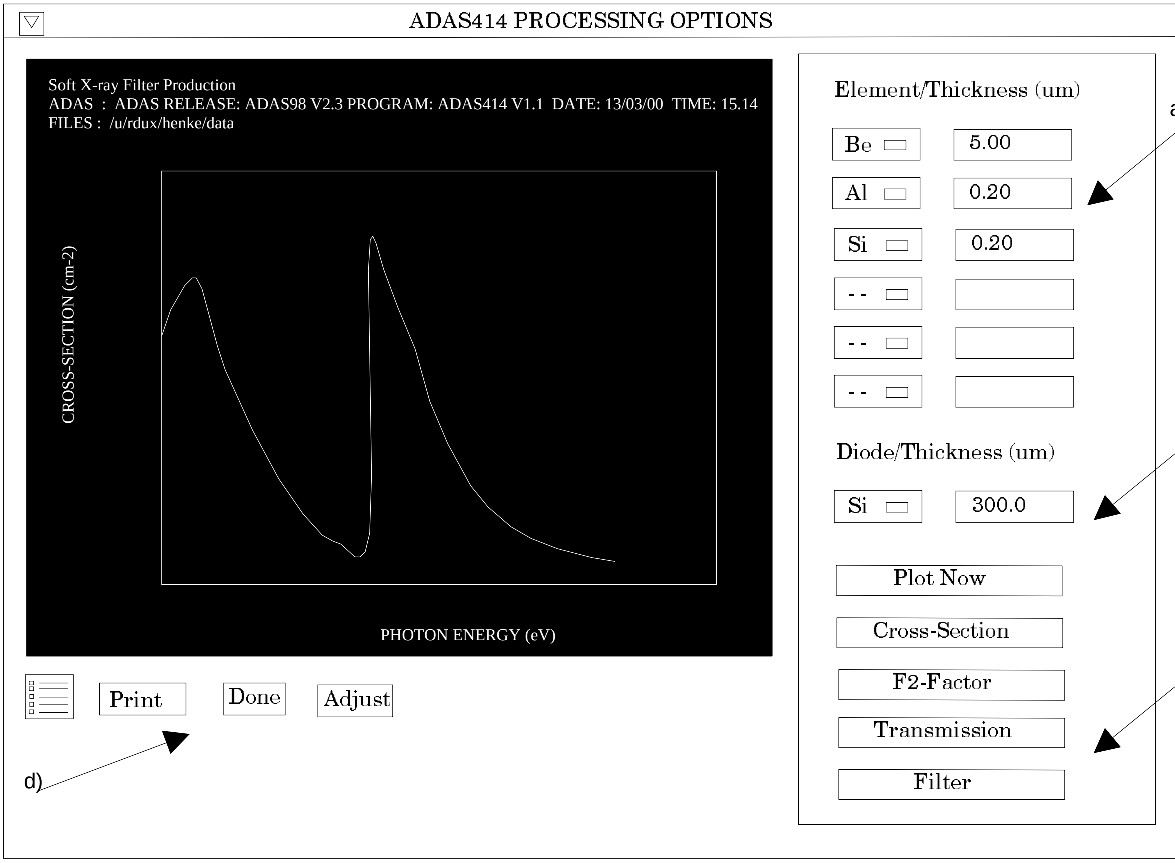
1. Data root a) shows the full pathway to the subdirectory of Henke cross-section data, *adf35*. Click the *Central Data* button to insert the default central ADAS pathway to the correct data type. Click the *User Data* button to insert the pathway to your own data. Note that your data must be held in a similar file structure to central ADAS, but with your identifier replacing the first *adas*, to use this facility.



2. The Data root can be edited directly. Click the *Edit Path Name* button first to permit editing.

3. Clicking the *Done* button moves you forward to the next window. Clicking the *Cancel* button takes you back to the previous window.

The **processing options window** has the appearance shown below.



4. The specification of the thin window layers is made at a). Click on the left drop-down list button to see the available elements and select an element. The layer thickness in micros is then entered in the editable box to the right. Up to six layers can be selected.

5. At b), the diode substrate absorbing thickness is specified in the same manner. The choice of substrate is restricted to silicon and germanium.

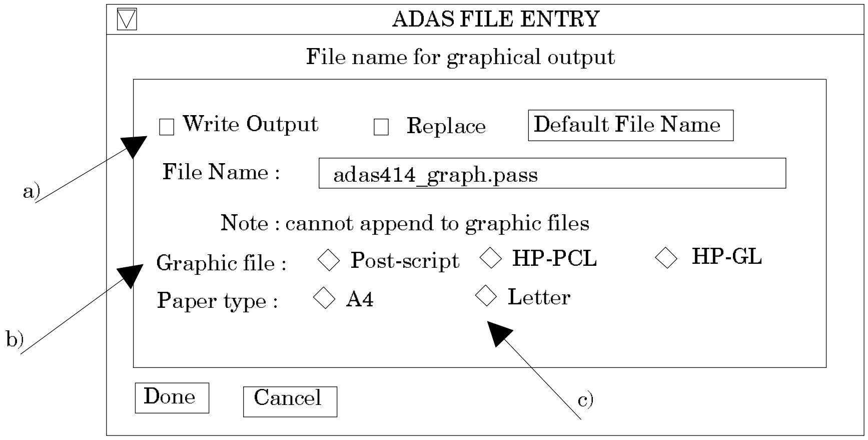
6. The displayable quantities are selected at c). Make the appropriate choice and finally press *Plot Now* to see the graph.

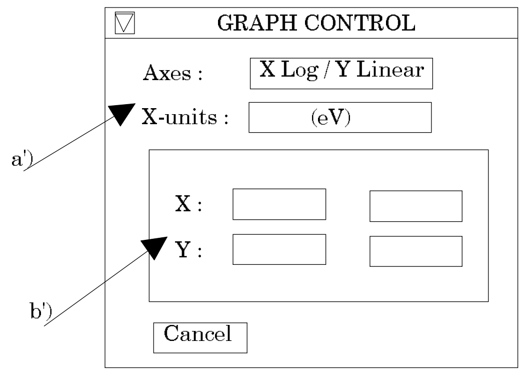
7. The buttons at d) allow printing of the graph, adjustment of the graph and progression to the final output of the numerical filter file.

8. The *Print* button pops up the File Entry widget as shown below. Specify the output file in the usual manner.

9. The *Adjust* button pops-up the Graph Control widget as shown below. This allows choices of logarithmic or linear plotting and X & Y axes minimum and maximum values.

10. At the base of the window, the icon for *Exit to Menu* is present. This quits the program and returns you to the ADAS series 4 menu. Remember that *Done* takes you forward to the next screen while *Cancel* takes you back to the previous screen.





The **text file options window** appearance is shown below

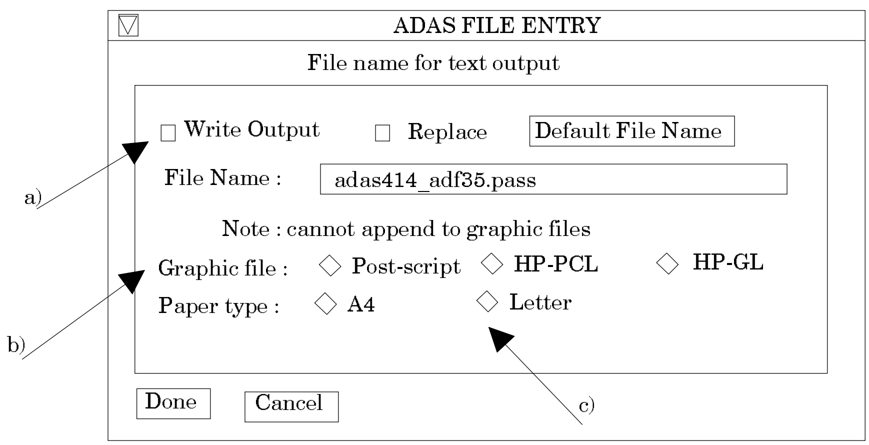


Illustration:

Table 5.14a

```
  510    5    0    1
--------------------------------------------------------------------------------
    72.800    99.700   111.600  1559.700  1839.000
--------------------------------------------------------------------------------
    10.000    10.162    10.326    10.493    10.663    10.835    11.011    11.189
    11.370    11.554    11.740    11.930    12.123    12.319    12.519    12.721
    12.927    13.136    13.348    13.564    13.784    14.007    14.233    14.463
       .         .         .
 21418.500 21765.000 22117.000 22474.699 22838.199 23207.600 23583.000 23964.400
 24352.000 24745.900 25146.199 25552.900 25966.199 26386.100 26812.900 27246.600
 27687.301 28135.100 28590.199 29052.600 29522.500 30000.000
 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000
 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000
 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000 -74.00000
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```
  -0.67921  -0.69827  -0.71745  -0.73674  -0.75615  -0.77567  -0.79529  -0.81501
  -0.83483  -0.85474  -0.87474  -0.89482  -0.91499  -0.93524  -0.95557  -0.97597
  -0.99644  -1.01698  -1.03759  -1.05826  -1.07899  -1.09979
C-------------------------------------------------------------------------------
C
C  Photon energy vs. Transmission of filter (T) x absorption in detector (A)
C
C  Units:  photon energy in eV
C          [T*A] in logarithm base 10
C
C  Data Source: http://xray.uu.se
C
C Energies of absorption edges (eV)
C       72.800    99.700   111.600  1559.700  1839.000
C
C  Filter :
C  Element   Thickness (micron)
C    Be       25.00000
C    Al        0.20000
C    Si        0.20000
C
C  Diode (absorber)
C  Element   Thickness (micron)
C    Si      300.00000
C
C  Code     : ADAS414
C  Producer : Hugh Summers
C  Date     : 13/03/00
C
C-------------------------------------------------------------------------------
```

Notes: