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MPLAW: A Multipulse-Scaling-Law Code Using Data-Base Interpolation

D. MERRITT CORDRAY

Optical Radiation Branch
Optical Sciences Division

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This report describes a program which provides the average focal-plane irradiance of a multiple-pulse truncated-Gaussian laser beam, given the input parameters necessary to describe the laser and the atmospheric conditions. The program contains a data base consisting of 720 data points which were obtained using the NRL propagation code. The irradiance is calculated by linear interpolation (or extrapolation) of a set of points from this data base. The program can be easily modified to use an expanded data base or to accept data for other beam shapes.

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MPLAW: A MULTIPULSE-SCALING-LAW CODE USING DATA-BASE INTERPOLATION

INTRODUCTION

Previous attempts to fit the focal-plane irradiance of a laser as a function of various physical or dimensionless parameters have generally led to more-or-less complicated polynomials. Experience has shown that reasonable fits can be obtained for certain beam shapes and a CW laser using sets of dimensionless parameters. This may be done by multiple-regression analysis of the output of a large number of computer runs. Such an expression usually increases in complexity and decreases in rms accuracy the less the beam resembles an infinite Gaussian. With the addition of another parameter (overlap number in the case of a multiple-pulse laser or range for a defocused laser), the multiple-regression analysis may give a solution having dozens of terms, some raised to high powers. Because of this the fit can take wide excursions within the range of parameters for which it is obtained and will deteriorate quickly outside that range.

This report describes a computer program which takes a new approach to the scaling-law problem. The program provides the average focal-plane irradiance of a multiple-pulse truncated-Gaussian laser as a function of eight physical parameters by performing a linear interpolation (or extrapolation) of a set of data points. These points come from a data base contained within the program. The data base consists of 720 points generated by the NRL propagation code and covers a wide range of parameters. The eight physical parameters used are:

f = focal length,

k = circular wavenumber = $2\pi/\lambda$,

α = absorption coefficient,

E = pulse energy,

Δt = pulse spacing,

v_0 = wind speed perpendicular to the beam,

Ω = slew rate, and

D = truncation diameter at the aperture (or the $1/e$ intensity radius $a = D/\sqrt{8}$).

Although this new scaling law by interpolation will require 2 or 3 times more computation time than the simple evaluation of a polynominal, it should prove at least as accurate as the multiple-regression analysis when the data cover a wide parameter range.

DESCRIPTION OF THE DATA BASE

An NRL propagation code with an adaptive coordinant system [1] (in which the distance between points in the computational mesh increases or decreases as the beam expands or contracts) was used to produce the data base used by the interpolation program. The aperture amplitude distribution was Gaussian, truncated at the e^{-2} intensity radius. The individual pulse lengths were assumed to be short compared with interpulse spacing. Self-blooming and atmospheric breakdown were ignored. The effects of jitter and turbulence may be added by root-sum-square addition of areas or other appropriate means.

The equation describing the propagation of the laser beam is solved in terms of five dimensionless parameters defined as

$$N_k = ka^2/f,$$

$$N_A = \alpha f,$$

$$N_s = \Omega f/v_0,$$

$$N_0 = 2\sqrt{2}\, a/v_0 \Delta t,$$

$$N_D = \frac{3N(\gamma - 1)}{c^2} \frac{k\alpha f E}{v_0 a \Delta t},$$

where

N = molecular refractivity of air = 0.154 cm^3/g,

γ = ratio of specific heats = 1.4,

c = sound speed = 340 m/s.

The areas computed by the propagation code are normalized to give the area relative to a focused, unbloomed truncated-Gaussian beam

$$A_{rel} = \frac{\text{area } N_k^2}{2.09\pi a^2}.$$

The relative focal-plane irradiance is given by $I_{rel} = 1/A_{rel}$.

The constant 2.09 is the ratio of the areas of truncated and infinite Gaussian beams in vacuum as calculated by the propagation code. This is within 1 percent of the theoretical [2] value 2.074.

The values of A_{rel} comprising the data base are arranged according to the values of the dimensionless parameters associated with them. Any combination of the physical parameters which produces the same dimensionless numbers will give the same A_{rel}. The values of the dimensionless parameters represented in the data base are

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$$N_0 = 1.0,\ 1.414,\ 2.828,\ 5.657,\ 11.314,$$

$$N_D = 0,\ 10,\ 50,\ 100,$$

$$N_s = 0,\ 2,\ 5,$$

$$N_k = 5,\ 20,\ 80,$$

$$N_A = 0.0,\ 0.1,\ 0.3,\ 0.6.$$

The 720 sets of N_0, N_D, N_s, N_k, N_A, and A_{rel} which make up the data base are listed in Appendix A. The average focal-plane irradiance inside the $1 - 1/e$ is given by

$$\bar{I} = \frac{0.3048 e^{-N_A} N_k^2 E}{\pi a^2 A_{\mathrm{rel}} \Delta t} .$$

The change in A_{rel} between adjacent points in the data base is small enough in any dimension that linear interpolation between these points is sufficiently accurate for most purposes. A higher order interpolation/extrapolation scheme can be readily added by any user finding it necessary.

INTERPOLATION PROGRAM

This algorithm has been programmed in two somewhat different forms, first on NRL's new Texas Instruments Advanced Scientific Computer (ASC) and more recently in an interactive form on the KRONOS time-sharing system, which uses a CDC machine. The time-sharing version is described below and is listed in Appendix B. It differs from the ASC version only in minor details, primarily due to differences in the two operating systems.

The program operates as shown in the steps listed below. Either physical or dimensionless parameters may be used. In both cases A_{rel} will be computed and printed. If physical parameters are used, the average focal-plane irradiance is printed as well. Parameters may be entered one set at a time or in groups of up to 20 values of each parameter, with the program cycling through all possible combinations of these numbers. The operational steps are:

1. Determine whether physical or dimensionless parameters will be used.

2. Determine how many values of each parameter will be read and set the loop indices accordingly.

3. Read the number of values of each parameter specified by the user, either five dimensionless parameters

$$N_0,\ N_D,\ N_s,\ N_k,\ N_A$$

or eight physical parameters

$$f,\ k,\ D,\ \alpha,\ \Omega,\ v_0,\ E,\ \Delta t.$$

4. For each set of parameters

a. If physical parameters were read, convert to dimensionless parameters for the interpolation/extrapolation.

b. Determine if any parameters are outside their allowed ranges. If so, print a message and skip to step 5 below. The allowed ranges are:

$$N_D \geqslant 0,$$

$$N_s \geqslant -1,$$

$$N_k > 0,$$

$$N_A \geqslant 0,$$

$$N_0 > 0. \text{ (For } 0 < N_0 \leqslant 1, A_{\text{rel}} \text{ is set equal to 1.)}$$

c. Determine for each parameter whether interpolation or extrapolation is required and pick the numbers from the data base to be used. If extrapolating, print a message to indicate this.

d. For each parameter the interpolation/extrapolation looks like #=A(lower index)+F*[A(upper)-A(lower)]. Determine the value of F for each parameter.

e. Perform the interpolation/extrapolation. The order in which this is done is

$$N_0,\ N_D,\ N_s,\ N_k,\ N_A.$$

f. Print A_{rel}. (A check is performed to assure that A_{rel} is not less than 1, as could happen when extrapolating to large N_s.)

g. If physical parameters were entered, compute and print I.

h. If this is a run with more than one set of parameters, repeat from step 4a until all combinations are done.

5. Ask the user if more data are to be entered. If so, return to step 1. Otherwise exit.

CONCLUSIONS

This report has described the development of an algorithm which provides the average focal-plane irradiance of a multiple-pulse truncated-Gaussian laser beam by linear interpolation or extrapolation of a set of points from a data base. This algorithm has been implemented in interactive form and is available to users on the KRONOS time-sharing system. A data base consisting of 720 data points obtained using an NRL propagation code is contained in the interpolation program. It is planned to continually update the data base as more data for this or other beam shapes become available.

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REFERENCES

1. "SSPARAMA: Nonlinear, Wave Optics Multipulse and CW Propagation Code Using Adaptive Coordinates," report to be published.

2. Private communication: value supplied by E.A. Phillips, Science Applications, Inc., Dec. 1975.

Appendix A

LISTING OF THE DATA BASE

N_0	N_D	N_s	N_k	N_A	A_{rel}
1.000	0	0	5	.00	1.000
1.000	0	0	5	.10	1.000
1.000	0	0	5	.30	1.000
1.000	0	0	5	.60	1.000
1.000	0	0	20	.00	1.000
1.000	0	0	20	.10	1.000
1.000	0	0	20	.30	1.000
1.000	0	0	20	.60	1.000
1.000	0	0	80	.00	1.000
1.000	0	0	80	.10	1.000
1.000	0	0	80	.30	1.000
1.000	0	0	80	.60	1.000
1.000	0	2	5	.00	1.000
1.000	0	2	5	.10	1.000
1.000	0	2	5	.30	1.000
1.000	0	2	5	.60	1.000
1.000	0	2	20	.00	1.000
1.000	0	2	20	.10	1.000
1.000	0	2	20	.30	1.000
1.000	0	2	20	.60	1.000
1.000	0	2	80	.00	1.000
1.000	0	2	80	.10	1.000
1.000	0	2	80	.30	1.000
1.000	0	2	80	.60	1.000
1.000	0	5	5	.00	1.000
1.000	0	5	5	.10	1.000
1.000	0	5	5	.30	1.000
1.000	0	5	5	.60	1.000
1.000	0	5	20	.00	1.000
1.000	0	5	20	.10	1.000
1.000	0	5	20	.30	1.000
1.000	0	5	20	.60	1.000
1.000	0	5	80	.00	1.000
1.000	0	5	80	.10	1.000
1.000	0	5	80	.30	1.000
1.000	0	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
1.000	10	0	5	.00	1.000
1.000	10	0	5	.10	1.000
1.000	10	0	5	.30	1.000
1.000	10	0	5	.60	1.000
1.000	10	0	20	.00	1.000
1.000	10	0	20	.10	1.000
1.000	10	0	20	.30	1.000
1.000	10	0	20	.60	1.000
1.000	10	0	80	.00	1.000
1.000	10	0	80	.10	1.000
1.000	10	0	80	.30	1.000
1.000	10	0	80	.60	1.000
1.000	10	2	5	.00	1.000
1.000	10	2	5	.10	1.000
1.000	10	2	5	.30	1.000
1.000	10	2	5	.60	1.000
1.000	10	2	20	.00	1.000
1.000	10	2	20	.10	1.000
1.000	10	2	20	.30	1.000
1.000	10	2	20	.60	1.000
1.000	10	2	80	.00	1.000
1.000	10	2	80	.10	1.000
1.000	10	2	80	.30	1.000
1.000	10	2	80	.60	1.000
1.000	10	5	5	.00	1.000
1.000	10	5	5	.10	1.000
1.000	10	5	5	.30	1.000
1.000	10	5	5	.60	1.000
1.000	10	5	20	.00	1.000
1.000	10	5	20	.10	1.000
1.000	10	5	20	.30	1.000
1.000	10	5	20	.60	1.000
1.000	10	5	80	.00	1.000
1.000	10	5	80	.10	1.000
1.000	10	5	80	.30	1.000
1.000	10	5	80	.60	1.000

N_0	N_D	N_s	N_k	N_A	A_{rel}
1.000	50	0	5	.00	1.000
1.000	50	0	5	.10	1.000
1.000	50	0	5	.30	1.000
1.000	50	0	5	.60	1.000
1.000	50	0	20	.00	1.000
1.000	50	0	20	.10	1.000
1.000	50	0	20	.30	1.000
1.000	50	0	20	.60	1.000
1.000	50	0	80	.00	1.000
1.000	50	0	80	.10	1.000
1.000	50	0	80	.30	1.000
1.000	50	0	80	.60	1.000
1.000	50	2	5	.00	1.000
1.000	50	2	5	.10	1.000
1.000	50	2	5	.30	1.000
1.000	50	2	5	.60	1.000
1.000	50	2	20	.00	1.000
1.000	50	2	20	.10	1.000
1.000	50	2	20	.30	1.000
1.000	50	2	20	.60	1.000
1.000	50	2	80	.00	1.000
1.000	50	2	80	.10	1.000
1.000	50	2	80	.30	1.000
1.000	50	2	80	.60	1.000
1.000	50	5	5	.00	1.000
1.000	50	5	5	.10	1.000
1.000	50	5	5	.30	1.000
1.000	50	5	5	.60	1.000
1.000	50	5	20	.00	1.000
1.000	50	5	20	.10	1.000
1.000	50	5	20	.30	1.000
1.000	50	5	20	.60	1.000
1.000	50	5	80	.00	1.000
1.000	50	5	80	.10	1.000
1.000	50	5	80	.30	1.000
1.000	50	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
1.000	100	0	5	.00	1.000
1.000	100	0	5	.10	1.000
1.000	100	0	5	.30	1.000
1.000	100	0	5	.60	1.000
1.000	100	0	20	.00	1.000
1.000	100	0	20	.10	1.000
1.000	100	0	20	.30	1.000
1.000	100	0	20	.60	1.000
1.000	100	0	80	.00	1.000
1.000	100	0	80	.10	1.000
1.000	100	0	80	.30	1.000
1.000	100	0	80	.60	1.000
1.000	100	2	5	.00	1.000
1.000	100	2	5	.10	1.000
1.000	100	2	5	.30	1.000
1.000	100	2	5	.60	1.000
1.000	100	2	20	.00	1.000
1.000	100	2	20	.10	1.000
1.000	100	2	20	.30	1.000
1.000	100	2	20	.60	1.000
1.000	100	2	80	.00	1.000
1.000	100	2	80	.10	1.000
1.000	100	2	80	.30	1.000
1.000	100	2	80	.60	1.000
1.000	100	5	5	.00	1.000
1.000	100	5	5	.10	1.000
1.000	100	5	5	.30	1.000
1.000	100	5	5	.60	1.000
1.000	100	5	20	.00	1.000
1.000	100	5	20	.10	1.000
1.000	100	5	20	.30	1.000
1.000	100	5	20	.60	1.000
1.000	100	5	80	.00	1.000
1.000	100	5	80	.10	1.000
1.000	100	5	80	.30	1.000
1.000	100	5	80	.60	1.000

N_0	N_D	N_s	N_k	N_A	A_{rel}
1.414	0	0	5	.00	1.000
1.414	0	0	5	.10	1.000
1.414	0	0	5	.30	1.000
1.414	0	0	5	.60	1.000
1.414	0	0	20	.00	1.000
1.414	0	0	20	.10	1.000
1.414	0	0	20	.30	1.000
1.414	0	0	20	.60	1.000
1.414	0	0	80	.00	1.000
1.414	0	0	80	.10	1.000
1.414	0	0	80	.30	1.000
1.414	0	0	80	.60	1.000
1.414	0	2	5	.00	1.000
1.414	0	2	5	.10	1.000
1.414	0	2	5	.30	1.000
1.414	0	2	5	.60	1.000
1.414	0	2	20	.00	1.000
1.414	0	2	20	.10	1.000
1.414	0	2	20	.30	1.000
1.414	0	2	20	.60	1.000
1.414	0	2	80	.00	1.000
1.414	0	2	80	.10	1.000
1.414	0	2	80	.30	1.000
1.414	0	2	80	.60	1.000
1.414	0	5	5	.00	1.000
1.414	0	5	5	.10	1.000
1.414	0	5	5	.30	1.000
1.414	0	5	5	.60	1.000
1.414	0	5	20	.00	1.000
1.414	0	5	20	.10	1.000
1.414	0	5	20	.30	1.000
1.414	0	5	20	.60	1.000
1.414	0	5	80	.00	1.000
1.414	0	5	80	.10	1.000
1.414	0	5	80	.30	1.000
1.414	0	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
1.414	10	0	5	.00	1.000
1.414	10	0	5	.10	1.000
1.414	10	0	5	.30	1.000
1.414	10	0	5	.60	1.000
1.414	10	0	20	.00	1.000
1.414	10	0	20	.10	1.003
1.414	10	0	20	.30	1.003
1.414	10	0	20	.60	1.003
1.414	10	0	80	.00	1.000
1.414	10	0	80	.10	1.019
1.414	10	0	80	.30	1.019
1.414	10	0	80	.60	1.019
1.414	10	2	5	.00	1.000
1.414	10	2	5	.10	1.020
1.414	10	2	5	.30	1.020
1.414	10	2	5	.60	1.020
1.414	10	2	20	.00	1.000
1.414	10	2	20	.10	1.001
1.414	10	2	20	.30	1.001
1.414	10	2	20	.60	1.001
1.414	10	2	80	.00	1.000
1.414	10	2	80	.10	1.000
1.414	10	2	80	.30	1.000
1.414	10	2	80	.60	1.000
1.414	10	5	5	.00	1.000
1.414	10	5	5	.10	1.020
1.414	10	5	5	.30	1.020
1.414	10	5	5	.60	1.020
1.414	10	5	20	.00	1.000
1.414	10	5	20	.10	1.001
1.414	10	5	20	.30	1.001
1.414	10	5	20	.60	1.001
1.414	10	5	80	.00	1.000
1.414	10	5	80	.10	1.000
1.414	10	5	80	.30	1.000
1.414	10	5	80	.60	1.000

N_0	N_D	N_s	N_k	N_A	A_{rel}
1.414	50	0	5	.00	1.000
1.414	50	0	5	.10	1.061
1.414	50	0	5	.30	1.056
1.414	50	0	5	.60	1.031
1.414	50	0	20	.00	1.000
1.414	50	0	20	.10	1.049
1.414	50	0	20	.30	1.067
1.414	50	0	20	.60	1.061
1.414	50	0	80	.00	1.000
1.414	50	0	80	.10	1.070
1.414	50	0	80	.30	1.065
1.414	50	0	80	.60	1.056
1.414	50	2	5	.00	1.000
1.414	50	2	5	.10	1.003
1.414	50	2	5	.30	1.002
1.414	50	2	5	.60	1.002
1.414	50	2	20	.00	1.000
1.414	50	2	20	.10	1.010
1.414	50	2	20	.30	1.010
1.414	50	2	20	.60	1.010
1.414	50	2	80	.00	1.000
1.414	50	2	80	.10	1.003
1.414	50	2	80	.30	1.002
1.414	50	2	80	.60	1.002
1.414	50	5	5	.00	1.000
1.414	50	5	5	.10	1.002
1.414	50	5	5	.30	1.002
1.414	50	5	5	.60	1.002
1.414	50	5	20	.00	1.000
1.414	50	5	20	.10	1.007
1.414	50	5	20	.30	1.007
1.414	50	5	20	.60	1.007
1.414	50	5	80	.00	1.000
1.414	50	5	80	.10	1.000
1.414	50	5	80	.30	1.000
1.414	50	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
1.414	100	0	5	.00	1.000
1.414	100	0	5	.10	1.213
1.414	100	0	5	.30	1.205
1.414	100	0	5	.60	1.197
1.414	100	0	20	.00	1.000
1.414	100	0	20	.10	1.312
1.414	100	0	20	.30	1.270
1.414	100	0	20	.60	1.243
1.414	100	0	80	.00	1.000
1.414	100	0	80	.10	1.292
1.414	100	0	80	.30	1.256
1.414	100	0	80	.60	1.307
1.414	100	2	5	.00	1.000
1.414	100	2	5	.10	1.017
1.414	100	2	5	.30	1.016
1.414	100	2	5	.60	1.015
1.414	100	2	20	.00	1.000
1.414	100	2	20	.10	1.025
1.414	100	2	20	.30	1.025
1.414	100	2	20	.60	1.024
1.414	100	2	80	.00	1.000
1.414	100	2	80	.10	1.015
1.414	100	2	80	.30	1.014
1.414	100	2	80	.60	1.012
1.414	100	5	5	.00	1.000
1.414	100	5	5	.10	1.006
1.414	100	5	5	.30	1.002
1.414	100	5	5	.60	1.002
1.414	100	5	20	.00	1.000
1.414	100	5	20	.10	1.014
1.414	100	5	20	.30	1.014
1.414	100	5	20	.60	1.013
1.414	100	5	80	.00	1.000
1.414	100	5	80	.10	1.017
1.414	100	5	80	.30	1.016
1.414	100	5	80	.60	1.014

N_0	N_D	N_s	N_k	N_A	A_{rel}
2.828	0	0	5	.00	1.000
2.828	0	0	5	.10	1.000
2.828	0	0	5	.30	1.000
2.828	0	0	5	.60	1.000
2.828	0	0	20	.00	1.000
2.828	0	0	20	.10	1.000
2.828	0	0	20	.30	1.000
2.828	0	0	20	.60	1.000
2.828	0	0	80	.00	1.000
2.828	0	0	80	.10	1.000
2.828	0	0	80	.30	1.000
2.828	0	0	80	.60	1.000
2.828	0	2	5	.00	1.000
2.828	0	2	5	.10	1.000
2.828	0	2	5	.30	1.000
2.828	0	2	5	.60	1.000
2.828	0	2	20	.00	1.000
2.828	0	2	20	.10	1.000
2.828	0	2	20	.30	1.000
2.828	0	2	20	.60	1.000
2.828	0	2	80	.00	1.000
2.828	0	2	80	.10	1.000
2.828	0	2	80	.30	1.000
2.828	0	2	80	.60	1.000
2.828	0	5	5	.00	1.000
2.828	0	5	5	.10	1.000
2.828	0	5	5	.30	1.000
2.828	0	5	5	.60	1.000
2.828	0	5	20	.00	1.000
2.828	0	5	20	.10	1.000
2.828	0	5	20	.30	1.000
2.828	0	5	20	.60	1.000
2.828	0	5	80	.00	1.000
2.828	0	5	80	.10	1.000
2.828	0	5	80	.30	1.000
2.828	0	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
2.828	10	0	5	.00	1.000
2.828	10	0	5	.10	1.080
2.828	10	0	5	.30	1.063
2.828	10	0	5	.60	1.041
2.828	10	0	20	.00	1.000
2.828	10	0	20	.10	1.062
2.828	10	0	20	.30	1.052
2.828	10	0	20	.60	1.019
2.828	10	0	80	.00	1.000
2.828	10	0	80	.10	1.060
2.828	10	0	80	.30	1.057
2.828	10	0	80	.60	1.037
2.828	10	2	5	.00	1.000
2.828	10	2	5	.10	1.000
2.828	10	2	5	.30	1.000
2.828	10	2	5	.60	1.000
2.828	10	2	20	.00	1.000
2.828	10	2	20	.10	1.009
2.828	10	2	20	.30	1.009
2.828	10	2	20	.60	1.009
2.828	10	2	80	.00	1.000
2.828	10	2	80	.10	1.023
2.828	10	2	80	.30	1.023
2.828	10	2	80	.60	1.023
2.828	10	5	5	.00	1.000
2.828	10	5	5	.10	1.000
2.828	10	5	5	.30	1.000
2.828	10	5	5	.60	1.000
2.828	10	5	20	.00	1.000
2.828	10	5	20	.10	1.005
2.828	10	5	20	.30	1.005
2.828	10	5	20	.60	1.005
2.828	10	5	80	.00	1.000
2.828	10	5	80	.10	1.023
2.828	10	5	80	.30	1.024
2.828	10	5	80	.60	1.024

N_0	N_D	N_s	N_k	N_A	A_{rel}
2.828	50	0	5	.00	1.000
2.828	50	0	5	.10	2.656
2.828	50	0	5	.30	2.467
2.828	50	0	5	.60	2.441
2.828	50	0	20	.00	1.000
2.828	50	0	20	.10	3.813
2.828	50	0	20	.30	3.390
2.828	50	0	20	.60	3.232
2.828	50	0	80	.00	1.000
2.828	50	0	80	.10	4.298
2.828	50	0	80	.30	3.764
2.828	50	0	80	.60	3.288
2.828	50	2	5	.00	1.000
2.828	50	2	5	.10	1.275
2.828	50	2	5	.30	1.251
2.828	50	2	5	.60	1.183
2.828	50	2	20	.00	1.000
2.828	50	2	20	.10	1.274
2.828	50	2	20	.30	1.256
2.828	50	2	20	.60	1.230
2.828	50	2	80	.00	1.000
2.828	50	2	80	.10	1.240
2.828	50	2	80	.30	1.227
2.828	50	2	80	.60	1.205
2.828	50	5	5	.00	1.000
2.828	50	5	5	.10	1.044
2.828	50	5	5	.30	1.042
2.828	50	5	5	.60	1.027
2.828	50	5	20	.00	1.000
2.828	50	5	20	.10	1.038
2.828	50	5	20	.30	1.036
2.828	50	5	20	.60	1.035
2.828	50	5	80	.00	1.000
2.828	50	5	80	.10	1.056
2.828	50	5	80	.30	1.050
2.828	50	5	80	.60	1.062

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N_0	N_D	N_s	N_k	N_A	A_{rel}
2.828	100	0	5	.00	1.000
2.828	100	0	5	.10	5.196
2.828	100	0	5	.30	5.264
2.828	100	0	5	.60	5.112
2.828	100	0	20	.00	1.000
2.828	100	0	20	.10	9.592
2.828	100	0	20	.30	9.234
2.828	100	0	20	.60	8.490
2.828	100	0	80	.00	1.000
2.828	100	0	80	.10	12.144
2.828	100	0	80	.30	11.267
2.828	100	0	80	.60	10.572
2.828	100	2	5	.00	1.000
2.828	100	2	5	.10	2.165
2.828	100	2	5	.30	2.205
2.828	100	2	5	.60	2.108
2.828	100	2	20	.00	1.000
2.828	100	2	20	.10	2.441
2.828	100	2	20	.30	2.229
2.828	100	2	20	.60	2.144
2.828	100	2	80	.00	1.000
2.828	100	2	80	.10	2.519
2.828	100	2	80	.30	2.439
2.828	100	2	80	.60	2.205
2.828	100	5	5	.00	1.000
2.828	100	5	5	.10	1.286
2.828	100	5	5	.30	1.276
2.828	100	5	5	.60	1.256
2.828	100	5	20	.00	1.000
2.828	100	5	20	.10	1.304
2.828	100	5	20	.30	1.283
2.828	100	5	20	.60	1.229
2.828	100	5	80	.00	1.000
2.828	100	5	80	.10	1.267
2.828	100	5	80	.30	1.259
2.828	100	5	80	.60	1.259

N_0	N_D	N_s	N_k	N_A	A_{rel}
5.657	0	0	5	.00	1.000
5.657	0	0	5	.10	1.000
5.657	0	0	5	.30	1.000
5.657	0	0	5	.60	1.000
5.657	0	0	20	.00	1.000
5.657	0	0	20	.10	1.000
5.657	0	0	20	.30	1.000
5.657	0	0	20	.60	1.000
5.657	0	0	80	.00	1.000
5.657	0	0	80	.10	1.000
5.657	0	0	80	.30	1.000
5.657	0	0	80	.60	1.000
5.657	0	2	5	.00	1.000
5.657	0	2	5	.10	1.000
5.657	0	2	5	.30	1.000
5.657	0	2	5	.60	1.000
5.657	0	2	20	.00	1.000
5.657	0	2	20	.10	1.000
5.657	0	2	20	.30	1.000
5.657	0	2	20	.60	1.000
5.657	0	2	80	.00	1.000
5.657	0	2	80	.10	1.000
5.657	0	2	80	.30	1.000
5.657	0	2	80	.60	1.000
5.657	0	5	5	.00	1.000
5.657	0	5	5	.10	1.000
5.657	0	5	5	.30	1.000
5.657	0	5	5	.60	1.000
5.657	0	5	20	.00	1.000
5.657	0	5	20	.10	1.000
5.657	0	5	20	.30	1.000
5.657	0	5	20	.60	1.000
5.657	0	5	80	.00	1.000
5.657	0	5	80	.10	1.000
5.657	0	5	80	.30	1.000
5.657	0	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
5.657	10	0	5	.00	1.000
5.657	10	0	5	.10	1.175
5.657	10	0	5	.30	1.143
5.657	10	0	5	.60	1.068
5.657	10	0	20	.00	1.000
5.657	10	0	20	.10	1.300
5.657	10	0	20	.30	1.179
5.657	10	0	20	.60	1.155
5.657	10	0	80	.00	1.000
5.657	10	0	80	.10	1.245
5.657	10	0	80	.30	1.217
5.657	10	0	80	.60	1.106
5.657	10	2	5	.00	1.000
5.657	10	2	5	.10	1.000
5.657	10	2	5	.30	1.000
5.657	10	2	5	.60	1.000
5.657	10	2	20	.00	1.000
5.657	10	2	20	.10	1.013
5.657	10	2	20	.30	1.011
5.657	10	2	20	.60	1.011
5.657	10	2	80	.00	1.000
5.657	10	2	80	.10	1.049
5.657	10	2	80	.30	1.043
5.657	10	2	80	.60	1.041
5.657	10	5	5	.00	1.000
5.657	10	5	5	.10	1.000
5.657	10	5	5	.30	1.000
5.657	10	5	5	.60	1.000
5.657	10	5	20	.00	1.000
5.657	10	5	20	.10	1.007
5.657	10	5	20	.30	1.007
5.657	10	5	20	.60	1.007
5.657	10	5	80	.00	1.000
5.657	10	5	80	.10	1.030
5.657	10	5	80	.30	1.029
5.657	10	5	80	.60	1.029

N_0	N_D	N_s	N_k	N_A	A_{rel}
5.657	50	0	5	.00	1.000
5.657	50	0	5	.10	5.463
5.657	50	0	5	.30	5.251
5.657	50	0	5	.60	4.566
5.657	50	0	20	.00	1.000
5.657	50	0	20	.10	10.228
5.657	50	0	20	.30	9.883
5.657	50	0	20	.60	8.057
5.657	50	0	80	.00	1.000
5.657	50	0	80	.10	14.471
5.657	50	0	80	.30	11.906
5.657	50	0	80	.60	10.072
5.657	50	2	5	.00	1.000
5.657	50	2	5	.10	2.035
5.657	50	2	5	.30	2.032
5.657	50	2	5	.60	1.753
5.657	50	2	20	.00	1.000
5.657	50	2	20	.10	2.234
5.657	50	2	20	.30	2.176
5.657	50	2	20	.60	1.868
5.657	50	2	80	.00	1.000
5.657	50	2	80	.10	2.416
5.657	50	2	80	.30	2.130
5.657	50	2	80	.60	1.882
5.657	50	5	5	.00	1.000
5.657	50	5	5	.10	1.214
5.657	50	5	5	.30	1.158
5.657	50	5	5	.60	1.136
5.657	50	5	20	.00	1.000
5.657	50	5	20	.10	1.218
5.657	50	5	20	.30	1.197
5.657	50	5	20	.60	1.130
5.657	50	5	80	.00	1.000
5.657	50	5	80	.10	1.221
5.657	50	5	80	.30	1.164
5.657	50	5	80	.60	1.161

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N_0	N_D	N_s	N_k	N_A	A_{rel}
5.657	100	0	5	.00	1.000
5.657	100	0	5	.10	13.521
5.657	100	0	5	.30	12.642
5.657	100	0	5	.60	11.783
5.657	100	0	20	.00	1.000
5.657	100	0	20	.10	27.688
5.657	100	0	20	.30	26.389
5.657	100	0	20	.60	23.237
5.657	100	0	80	.00	1.000
5.657	100	0	80	.10	40.567
5.657	100	0	80	.30	37.536
5.657	100	0	80	.60	33.964
5.657	100	2	5	.00	1.000
5.657	100	2	5	.10	5.826
5.657	100	2	5	.30	5.801
5.657	100	2	5	.60	5.052
5.657	100	2	20	.00	1.000
5.657	100	2	20	.10	6.934
5.657	100	2	20	.30	6.694
5.657	100	2	20	.60	6.047
5.657	100	2	80	.00	1.000
5.657	100	2	80	.10	7.554
5.657	100	2	80	.30	6.813
5.657	100	2	80	.60	6.056
5.657	100	5	5	.00	1.000
5.657	100	5	5	.10	2.319
5.657	100	5	5	.30	2.127
5.657	100	5	5	.60	1.989
5.657	100	5	20	.00	1.000
5.657	100	5	20	.10	2.299
5.657	100	5	20	.30	2.205
5.657	100	5	20	.60	2.148
5.657	100	5	80	.00	1.000
5.657	100	5	80	.10	2.354
5.657	100	5	80	.30	2.264
5.657	100	5	80	.60	2.189

N_0	N_D	N_s	N_k	N_A	A_{rel}
11.314	0	0	5	.00	1.000
11.314	0	0	5	.10	1.000
11.314	0	0	5	.30	1.000
11.314	0	0	5	.60	1.000
11.314	0	0	20	.00	1.000
11.314	0	0	20	.10	1.000
11.314	0	0	20	.30	1.000
11.314	0	0	20	.60	1.000
11.314	0	0	80	.00	1.000
11.314	0	0	80	.10	1.000
11.314	0	0	80	.30	1.000
11.314	0	0	80	.60	1.000
11.314	0	2	5	.00	1.000
11.314	0	2	5	.10	1.000
11.314	0	2	5	.30	1.000
11.314	0	2	5	.60	1.000
11.314	0	2	20	.00	1.000
11.314	0	2	20	.10	1.000
11.314	0	2	20	.30	1.000
11.314	0	2	20	.60	1.000
11.314	0	2	80	.00	1.000
11.314	0	2	80	.10	1.000
11.314	0	2	80	.30	1.000
11.314	0	2	80	.60	1.000
11.314	0	5	5	.00	1.000
11.314	0	5	5	.10	1.000
11.314	0	5	5	.30	1.000
11.314	0	5	5	.60	1.000
11.314	0	5	20	.00	1.000
11.314	0	5	20	.10	1.000
11.314	0	5	20	.30	1.000
11.314	0	5	20	.60	1.000
11.314	0	5	80	.00	1.000
11.314	0	5	80	.10	1.000
11.314	0	5	80	.30	1.000
11.314	0	5	80	.60	1.000

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N_0	N_D	N_s	N_k	N_A	A_{rel}
11.314	10	0	5	.00	1.000
11.314	10	0	5	.10	1.354
11.314	10	0	5	.30	1.298
11.314	10	0	5	.60	1.231
11.314	10	0	20	.00	1.000
11.314	10	0	20	.10	1.741
11.314	10	0	20	.30	1.571
11.314	10	0	20	.60	1.304
11.314	10	0	80	.00	1.000
11.314	10	0	80	.10	1.736
11.314	10	0	80	.30	1.488
11.314	10	0	80	.60	1.271
11.314	10	2	5	.00	1.000
11.314	10	2	5	.10	1.016
11.314	10	2	5	.30	1.008
11.314	10	2	5	.60	1.000
11.314	10	2	20	.00	1.000
11.314	10	2	20	.10	1.030
11.314	10	2	20	.30	1.026
11.314	10	2	20	.60	1.020
11.314	10	2	80	.00	1.000
11.314	10	2	80	.10	1.021
11.314	10	2	80	.30	1.048
11.314	10	2	80	.60	1.039
11.314	10	5	5	.00	1.000
11.314	10	5	5	.10	1.000
11.314	10	5	5	.30	1.000
11.314	10	5	5	.60	1.000
11.314	10	5	20	.00	1.000
11.314	10	5	20	.10	1.000
11.314	10	5	20	.30	1.000
11.314	10	5	20	.60	1.000
11.314	10	5	80	.00	1.000
11.314	10	5	80	.10	1.036
11.314	10	5	80	.30	1.035
11.314	10	5	80	.60	1.033

N_0	N_D	N_s	N_k	N_A	A_{rel}
11.314	50	0	5	.00	1.000
11.314	50	0	5	.10	6.570
11.314	50	0	5	.30	5.953
11.314	50	0	5	.60	5.057
11.314	50	0	20	.00	1.000
11.314	50	0	20	.10	17.798
11.314	50	0	20	.30	14.808
11.314	50	0	20	.60	11.426
11.314	50	0	80	.00	1.000
11.314	50	0	80	.10	29.072
11.314	50	0	80	.30	23.087
11.314	50	0	80	.60	16.939
11.314	50	2	5	.00	1.000
11.314	50	2	5	.10	3.016
11.314	50	2	5	.30	2.654
11.314	50	2	5	.60	2.421
11.314	50	2	20	.00	1.000
11.314	50	2	20	.10	3.861
11.314	50	2	20	.30	3.447
11.314	50	2	20	.60	2.955
11.314	50	2	80	.00	1.000
11.314	50	2	80	.10	4.437
11.314	50	2	80	.30	4.176
11.314	50	2	80	.60	3.020
11.314	50	5	5	.00	1.000
11.314	50	5	5	.10	1.480
11.314	50	5	5	.30	1.506
11.314	50	5	5	.60	1.403
11.314	50	5	20	.00	1.000
11.314	50	5	20	.10	1.588
11.314	50	5	20	.30	1.444
11.314	50	5	20	.60	1.417
11.314	50	5	80	.00	1.000
11.314	50	5	80	.10	1.496
11.314	50	5	80	.30	1.438
11.314	50	5	80	.60	1.397

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N_0	N_D	N_s	N_k	N_A	A_{rel}
11.314	100	0	5	.00	1.000
11.314	100	0	5	.10	13.783
11.314	100	0	5	.30	12.599
11.314	100	0	5	.60	11.344
11.314	100	0	20	.00	1.000
11.314	100	0	20	.10	41.799
11.314	100	0	20	.30	39.364
11.314	100	0	20	.60	33.986
11.314	100	0	80	.00	1.000
11.314	100	0	80	.10	92.812
11.314	100	0	80	.30	77.421
11.314	100	0	80	.60	56.499
11.314	100	2	5	.00	1.000
11.314	100	2	5	.10	7.534
11.314	100	2	5	.30	7.221
11.314	100	2	5	.60	6.401
11.314	100	2	20	.00	1.000
11.314	100	2	20	.10	12.941
11.314	100	2	20	.30	11.771
11.314	100	2	20	.60	10.282
11.314	100	2	80	.00	1.000
11.314	100	2	80	.10	16.571
11.314	100	2	80	.30	15.976
11.314	100	2	80	.60	11.787
11.314	100	5	5	.00	1.000
11.314	100	5	5	.10	3.637
11.314	100	5	5	.30	3.369
11.314	100	5	5	.60	3.197
11.314	100	5	20	.00	1.000
11.314	100	5	20	.10	4.164
11.314	100	5	20	.30	4.009
11.314	100	5	20	.60	3.393
11.314	100	5	80	.00	1.000
11.314	100	5	80	.10	4.618
11.314	100	5	80	.30	3.970
11.314	100	5	80	.60	3.440

Appendix B

FORTRAN LISTING OF PROGRAM MPLAW

```
00100 PROGRAM MPLAW(INPUT,OUTPUT)
00110 REAL NO,ND,NS,NK,NA
00120 DIMENSION PNS(3),PNO(5),PND(4),PNK(3),PNA(4),A(720),B(32)
00130 DIMENSION X1(20),X2(20),X3(20),X4(20),X5(20),X6(20),X7(20),X8(20)
00140 DATA (PNS=0.,2.,5.),(PNO=1.,1.414,2.828,5.657,11.314),
00150+      (PND=0.,10.,50.,100.),(PNA=0.,0.1,0.3,0.6),
00160+      (PNK=5.,20.,80.),(PI=3.141592654)
00170*
00180*     DATA BASE.
00190*
00200 DATA(A=187*1.,1.08,1.175,1.354,1.,1.061,2.656,5.463,6.57,1.,1.213,
00210+      5.196,13.521,13.783,6*1.,1.02,2*1.,1.016,1.,1.003,1.275,2.035,
00220+      3.016,1.,1.017,2.165,5.826,7.534,6*1.,1.02,4*1.,1.002,1.044,1.214,
00230+      1.48,1.,1.006,1.286,2.319,3.637,6*1.,1.003,1.062,1.3,1.741,1.,
00240+      1.049,3.813,10.228,17.798,1.,1.312,9.592,27.688,41.799,6*1.,1.001,
00250+      1.009,1.013,1.03,1.,1.01,1.274,2.234,3.861,1.,1.025,2.441,6.934,
00260+      12.941,6*1.,1.001,1.005,1.007,2*1.,1.007,1.038,1.218,1.588,1.,
00270+      1.014,1.304,2.299,4.164,6*1.,1.019,1.06,1.245,1.736,1.,1.07,4.298,
00280+      14.471,29.072,1.,1.292,12.144,40.567,92.812,7*1.,1.023,1.049,
00290+      1.021,1.,1.003,1.24,2.416,4.437,1.,1.015,2.519,7.554,16.571,7*1.,
00300+      1.023,1.03,1.036,2*1.,1.056,1.221,1.496,1.,1.017,1.267,2.354,
00310+      4.618,7*1.,1.063,1.143,1.298,1.,1.056,2.467,5.251,5.953,1.,1.205,
00320+      5.264,12.642,12.599,6*1.,1.02,2*1.,1.008,1.,1.002,1.251,2.032,
00330+      2.654,1.,1.016,2.205,5.801,7.221,6*1.,1.02,4*1.,1.002,1.042,1.158,
00340+      1.506,1.,1.002,1.276,2.127,3.369,6*1.,1.003,1.052,1.179,1.571,
00350+      1.,1.067,3.39,9.883,14.808,1.,1.27,9.234,26.389,39.364,6*1.,1.001,
00360+      1.009,1.011,1.026,1.,1.01,1.256,2.176,3.447,1.,1.025,2.229,6.694,
00370+      11.771,6*1.,1.001,1.005,1.007,2*1.,1.007,1.036,1.197,1.444,1.,1.014,
00380+      1.283,2.205,4.009,6*1.,1.019,1.057,1.217,1.488,1.,1.065,3.764,11.906
00390 DATA (A(I),I=495,720)/23.087,1.,1.256,11.267,37.536,77.421,7*1.,1.023,
00400+      1.043,1.048,1.,1.002,1.227,2.13,4.176,1.,1.014,2.439,6.813,15.976,
00410+      7*1.,1.024,1.029,1.035,2*1.,1.05,1.164,1.438,1.,1.016,1.259,2.264,
00420+      3.97,7*1.,1.041,1.068,1.231,1.,1.031,2.441,4.566,5.057,1.,1.197,
00430+      5.112,11.783,11.344,6*1.,1.02,4*1.,1.002,1.183,1.753,2.421,1.,
00440+      1.015,2.108,5.052,6.401,6*1.,1.02,4*1.,1.002,1.027,1.136,1.403,1.,
00450+      1.002,1.256,1.989,3.197,6*1.,1.003,1.019,1.155,1.304,1.,1.061,
00460+      3.232,8.057,11.426,1.,1.243,8.49,23.237,33.986,6*1.,1.001,1.009,
00470+      1.011,1.02,1.,1.01,1.23,1.868,2.955,1.,1.024,2.144,6.047,10.282,
00480+      6*1.,1.001,1.005,1.007,2*1.,1.007,1.035,1.13,1.417,1.,1.013,1.229,
00490+      2.148,3.393,6*1.,1.019,1.037,1.106,1.271,1.,1.056,3.288,10.072,
00500+      16.939,1.,1.307,10.572,33.964,56.499,7*1.,1.023,1.041,1.039,1.,
00510+      1.002,1.205,1.882,3.02,1.,1.012,2.205,6.056,11.787,7*1.,1.024,
00520+      1.029,1.033,2*1.,1.062,1.161,1.397,1.,1.014,1.259,2.189,3.44/
00530 NAME(I1,I2,I3,I4,I5)=I1+5*(I2-1)+20*(I3-1)+60*(I4-1)+180*(I5-1)
00540*
00550*     BEGIN EXECUTABLE CODE.
00560*
00570 REIGHT=SQRT(8.)
00580 PRINT,* DO YOU NEED HELP IN USING THIS PROGRAM--YES OR NO?*
00590 READ 1,I
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00600 1 FORMAT(A2)
00610 IF(I.NE.2HYE) GO TO 2
00620 PRINT 8
00630 8 FORMAT(/)
00640*
00650*    PRINT PROGRAM DESCRIPTION, IF REQUESTED.
00660*
00670 PRINT 3
00680 3 FORMAT(*       THIS PROGRAM PERFORMS A LINEAR INTERPOLATION (OR *,
00690+  *EXTRAPOLATION) TO*,/,* OBTAIN VALUES OF AVERAGE FOCAL PLANE *,
00700+  *IRRADIANCE OF A GAUSSIAN BEAM TRUN-*,/,* CATED AT THE E*,2H**,
00710+  *-2 INTENSITY RADIUS.  THE DATA BASE CONTAINS 720 POINTS*,/,
00720+  * GENERATED BY THE NRL PROPAGATION CODE.  THE IRRADIANCE CALCULAT*,
00730+  *ED IS*,/,* THE AVERAGE IRRADIANCE INSIDE THE AREA CONTAINING 1-*,
00740+  *1/E (.632) OF THE*,/,* FLUX.*,/,*       YOU MAY ENTER EITHER*,
00750+  * PHYSICAL OR DIMENSIONLESS PARAMETERS.  THE*,/,* PHYSICAL PARAME*,
00760+  *TERS REQUIRED ARE:*)
00770 PRINT,*      F = FOCAL LENGTH*
00780 PRINT,*      K = WAVE NUMBER = 2 PI / LAMBDA*
00790 PRINT,*      ALPHA = ABSORPTION*
00800 PRINT,*      DIAM = DIAMETER OF APERTURE (THE 1/E APERTURE INTENSITY*
00810 PRINT,*                 RADIUS, A, IS DIAM/SQRT(8))*
00820 PRINT,*      V = WIND SPEED PERPENDICULAR TO THE BEAM*
00830 PRINT,*      OMEGA = BEAM SLUING RATE*
00840 PRINT,*      E = EMITTED ENERGY PER PULSE*
00850 PRINT,*      DT = INTERPULSE SPACING*
00860 PRINT,* THE DIMENSIONLESS PARAMETERS ARE DEFINED AS:*
00870 PRINT 4
00880 4 FORMAT(5X,24HNC = SQRT(8) * A / V DT ,/,5X,25HND = 3 * N * (GAMMA-1) *
00890+      41HK * ALPHA * F * E / ( C**2 * A / V DT )  ,/,5X,
00900+      18HNS = OMEGA * F / V,/,5X,17HNK = K * A**2 / F,/,5X,
00910+      14HNA = ALPHA * F,/,5X,*    WHERE N=MOLECULAR REFRACTIVITY=.154*,
00920+      *, GAMMA=RATIO OF SPECIFIC *,/,9X,*HEATS=1.4, AND C=SOUND SPEED=*,
00930+      *340M/S.*)
00940 PRINT 5
00950 5 FORMAT(*       YOU MAY ENTER PARAMETERS ONE SET AT A TIME (ANSWER *,
00960+  *"SINGLE" TO "SINGLE*,/,* OR MULTIPLE RUN?") OR YOU MAY ENTER UP *,
00970+  *TO 20 VALUES OF EACH PARAMETER *,/,* (ANSWER "MULTIPLE").  IF Y*,
00980+  *OUR ANSWER WAS "SINGLE" YOU WILL BE ASKED TO*,/,* ENTER THE FIVE*,
00990+  * DIMENSIONLESS OR EIGHT PHYSICAL PARAMETERS.  IF YOUR AN-*,/,* SWER*,
01000+  * WAS "MULTIPLE" YOU WILL FIRST BE ASKED HOW MANY VALUES OF*,
01010+  * EACH PARAMETER*,/,* YOU WILL ENTER, THEN YOU WILL BE ASKED TO ENTER*,
01020+  * THE PARAMETERS*,/,*       THE OUTPUT CONSISTS OF ONE OR TWO *,
01030+  *NUMBERS, DEPENDING ON WHETHER*,/,* YOU ARE USING PHYSICAL OR DIM*,
01040+  *ENSIONLESS PARAMETERS.  IN EITHER CASE,*,/,* AREL IS PRINTED.  *,
01050+  *AREL IS THE NORMALIZED FOCAL AREA CONTAINING 1-1/E OF*,/,* THE *,
01060+  *FLUX.  IT IS DEFINED AS AREL=AREA(CM*,20H**2)*NK**2/(2.09*A*A,
01070+  *).  IF*,/,* PHYSICAL PARAMETERS ARE USED, THE AVERAGE FOCAL PLANE*,
01080+  * IRRADIANCE IS*,/,* PRINTED.  THIS IS GIVEN BY:*)
01090 PRINT 6
01100 6 FORMAT(12X,44HI=.3024*E*EXP(-NA)*NK**2/(2.09*AREL*PI*A**2),*,*,/,
01110+  *       WHEN ASKED "DO YOU HAVE ANOTHER RUN?", REPLY "MULTIPLE" OR*,
01120+  * "SIN=*,/,* GLE" IF YOU WISH TO CONTINUE.  OTHERWISE ENTER "END"*)
01130 PRINT 8
01140 2 CONTINUE
01150*
01160*    DETERMINE IF PHYS. OR DIM. PARAMETERS WILL BE USED.
01170*
01180 PRINT,* WILL YOU USE PHYSICAL OR DIMENSIONLESS PARAMETERS?*
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01190 IF(I.NE.2HYE) GO TO 9
01200 I=2HNO
01210 PRINT,* ANSWER PHYS OR DIM*
01220 9 READ 1,IPARAM
01230*
01240*    DETERMINE IF THIS IS A SINGLE OR MULTIPLE RUN.
01250*
01260 PRINT,* SINGLE OR MULTIPLE RUN?*
01270 READ 1,MPARAM
01280*
01290*    BEGINNING OF EACH RUN.
01300*
01310 10 IU1=IU2=IU3=IU4=IU5=IU6=IU7=IU8=1
01320 IF(MPARAM.EQ.2HSI) GO TO 12
01330 PRINT,* ENTER NUMBER OF VALUES OF THESE PARAMETERS:*
01340 IF(IPARAM.EQ.2HDI) GO TO 11
01350*
01360*    MULTIPLE RUN, PHYSICAL PARAMETERS.
01370*    ENTER DATA.
01380*
01390 PRINT,* F K ALPHA DIAM V OMEGA E DT*
01400 READ,IU1,IU2,IU3,IU4,IU5,IU6,IU7,IU8
01410 PRINT 101,IU1
01420 101 FORMAT(* ENTER*,I3,* VALUE(S) OF F(KM)*)
01430 READ,(X1(I),I=1,IU1)
01440 PRINT 102,IU2
01450 102 FORMAT(* ENTER*,I3,* VALUE(S) OF K(/CM)*)
01460 READ,(X2(I),I=1,IU2)
01470 PRINT 103,IU3
01480 103 FORMAT(* ENTER*,I3,* VALUE(S) OF ALPHA(/KM)*)
01490 READ,(X3(I),I=1,IU3)
01500 PRINT 104,IU4
01510 104 FORMAT(* ENTER*,I3,* VALUE(S) OF DIAM(CM)*)
01520 READ,(X4(I),I=1,IU4)
01530 PRINT 105,IU5
01540 105 FORMAT(* ENTER*,I3,* VALUE(S) OF V(M/S)*)
01550 READ,(X5(I),I=1,IU5)
01560 PRINT 106,IU6
01570 106 FORMAT(* ENTER*,I3,* VALUE(S) OF OMEGA(RAD/SEC)*)
01580 READ,(X6(I),I=1,IU6)
01590 PRINT 107,IU7
01600 107 FORMAT(* ENTER*,I3,* VALUE(S) OF E(KJ)*)
01610 READ,(X7(I),I=1,IU7)
01620 PRINT 108,IU8
01630 108 FORMAT(* ENTER*,I3,* VALUE(S) OF DT(SEC)*)
01640 READ,(X8(I),I=1,IU8)
01650 GO TO 18
01660*
01670*    MULTIPLE RUN, DIMENSIONLESS PARAMETERS.
01680*    ENTER DATA.
01690*
01700 11 PRINT,* NO ND NS NK NA*
01710 READ,IU4,IU5,IU6,IU7,IU8
01720 PRINT 114,IU4
01730 114 FORMAT(* ENTER*,I3,* VALUE(S) OF NO*)
01740 READ,(X4(I),I=1,IU4)
01750 PRINT 115,IU5
01760 115 FORMAT(* ENTER*,I3,* VALUE(S) OF ND*)
01770 READ,(X5(I),I=1,IU5)
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01780 PRINT 116,IU6
01790 116 FORMAT(* ENTER*,I3,* VALUE(S) OF NS*)
01800 READ,(X6(I),I=1,IU6)
01810 PRINT 117,IU7
01820 117 FORMAT(* ENTER*,I3,* VALUE(S) OF NK*)
01830 READ,(X7(I),I=1,IU7)
01840 PRINT 118,IU8
01850 118 FORMAT(* ENTER*,I3,* VALUE(S) OF NA*)
01860 READ,(X8(I),I=1,IU8)
01870 GO TO 18
01880 12 IF(IPARAM.EQ.2HPH) GO TO 15
01890*
01900*     SINGLE RUN, DIMENSIONLESS PARAMETERS.
01910*     ENTER DATA.
01920*
01930 PRINT,* ENTER DIMENSIONLESS PARAMETERS:*
01940 PRINT,*  NO  ND  NS  NK  NA*
01950 READ,X4(1),X5(1),X6(1),X7(1),X8(1)
01960 GO TO 18
01970*
01980*     SINGLE RUN, PHYSICAL PARAMETERS.
01990*     ENTER DATA.
02000*
02010 15 PRINT,* ENTER: F(KM) K(/CM) ALPHA(/KM) DIAM(CM) V(M/S) OMEGA(RAD/S)*,
02020+      * E(KJ) DT(SEC)*
02030 READ,X1(1),X2(1),X3(1),X4(1),X5(1),X6(1),X7(1),X8(1)
02040*
02050*     BEGIN DO LOOPS FOR MULTIPLE RUNS.
02060*     ASSIGN INPUT DATA TO CORRECT VARIABLES.
02070*
02080 18 DO 100 L1=1,IU1
02090 F=X1(L1)
02100 DO 100 L2=1,IU2
02110 WN=X2(L2)
02120 DO 100 L3=1,IU3
02130 ALF=X3(L3)
02140 DO 100 L4=1,IU4
02150 WIDTH=X4(L4)/REIGHT
02160 IF(IPARAM.EQ.2HPH) D=X4(L4)
02170 IF(IPARAM.EQ.2HDI) ND=X4(L4)
02180 DO 100 L5=1,IU5
02190 IF(IPARAM.EQ.2HPH) V=X5(L5)
02200 IF(IPARAM.EQ.2HDI) ND=X5(L5)
02210 DO 100 L6=1,IU6
02220 IF(IPARAM.EQ.2HPH) OM=X6(L6)
02230 IF(IPARAM.EQ.2HDI) NS=X6(L6)
02240 DO 100 L7=1,IU7
02250 IF(IPARAM.EQ.2HPH) E=X7(L7)
02260 IF(IPARAM.EQ.2HDI) NK=X7(L7)
02270 DO 100 L8=1,IU8
02280 IF(IPARAM.EQ.2HPH) DT=X8(L8)
02290 IF(IPARAM.EQ.2HDI) NA=X8(L8)
02300 IF(IPARAM.EQ.2HDI) GO TO 22
02310*
02320*     IF PHYSICAL PARAMETERS WERE READ, COMPUTE DIMENSIONLESS PARAMETERS.
02330*
02340 NA=ALF*F
02350 NK=WN*D*D*.125E-5/F
02360 NS=OM*F*1E3/V
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```
02370 NO=D/(100.*V*DT)
02380 ND=1.5986*WN*ALF*F*E/(D/SQRT(8.)*DT*V*100.)
02390 22 CONTINUE
02400 PRINT 21,NO,ND,NS,NK,NA
02410 21 FORMAT(/,* NO=*,F6.3,5X,*ND=*,F7.2,5X,*NS=*,F6.3,5X,*NK=*,F6.2,5X,
02420+      *NA=*,F5.3)
02430*
02440*     CHECK FOR PARAMETERS OUTSIDE ALLOWED RANGES.
02450*
02460 IERR=0
02470 IF(NA.GE.0.) GO TO 23
02480 PRINT,* ABSORPTION NUMBER IS NEGATIVE*
02490 IERR=IERR+1
02500 23 IF(NK.GT.0.) GO TO 24
02510 PRINT,* FRESNEL NUMBER IS LESS THAN OR EQUAL TO ZERO*
02520 IERR=IERR+1
02530 24 IF(NS.GE.-1.) GO TO 25
02540 PRINT,* SLUING NUMBER IS NEGATIVE*
02550 IERR=IERR+1
02560 25 IF(ND.GE.0.) GO TO 26
02570 PRINT,* DISTORTION NUMBER IS NEGATIVE*
02580 IERR=IERR+1
02590 26 IF(NO.GT.1.) GO TO 28
02600 IF(NO.LE.0.) GO TO 27
02610 PRINT,* OVERLAP NUMBER IS BETWEEN ZERO AND ONE*
02620 AREL=1.
02630 IF(IERR.EQ.0) GO TO 68
02640 27 PRINT,* OVERLAP NUMBER IS LESS THAN OR EQUAL TO ZERO*
02650 IERR=IERR+1
02660 28 IF(IERR.EQ.0) GO TO 30
02670 PRINT 29,IERR
02680  29 FORMAT(8H *******,I3,* PARAMETERS HAD VALUES OUTSIDE THEIR*,
02690+     * ALLOWED RANGES--*)
02700 IF(MPARAM.EQ.2HSI) PRINT,8H *******,* CHECK YOUR DATA AND REENTER*
02710 GO TO 100
02720 30 CONTINUE
02730*
02740*     FIND INDEX OF POINTS TO BE INTERPOLATED.
02750*
02760 INO=INO=INS=INK=INA=1
02770 DO 35 I=2,3
02780 IF(NO.GE.PNO(I)) INO=I
02790 IF(ND.GE.PND(I)) IND=I
02800 IF(NS.GE.PNS(I)) INS=I
02810 IF(NK.GE.PNK(I)) INK=I
02820 IF(NA.GE.PNA(I)) INA=I
02830 35 CONTINUE
02840 IF(NO.GE.PNO(4)) INO=4
02850 IF(ND.GE.PND(4)) IND=4
02860 IF(NA.GE.PNA(4)) INA=4
02870 IF(NO.GE.PNO(5)) INO=5
02880*
02890*     FIND FRACTIONS AND TEST FOR EXTRAPOLATION.
02900*
02910 IF(INO.NE.5) GO TO 41
02920 INO=4
02930 IF(NO.NE.PNO(5)) PRINT 40
02940 40 FORMAT(* THE VALUE OF NO IS EXTRAPOLATED*)
02950 41 FO=(NO-PNO(INO))/(PNO(INO+1)-PNO(INO))
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IF(IND.NE.4) GO TO 43
IND=3
IF(ND.NE.PND(4)) PRINT 42
42 FORMAT(* THE VALUE OF ND IS EXTRAPOLATED*)
43 FD=(ND-PND(IND))/(PND(IND+1)-PND(IND))
IF(INS.NE.3) GO TO 45
INS=2
IF(NS.NE.PNS(3)) PRINT 44
44 FORMAT(* THE VALUE OF NS IS EXTRAPOLATED*)
45 FS=(NS-PNS(INS))/(PNS(INS+1)-PNS(INS))
IF(INK.NE.3) GO TO 47
INK=2
IF(NK.NE.PNK(3)) PRINT 46
46 FORMAT(* THE VALUE OF NK IS EXTRAPOLATED*)
47 FK=(NK-PNK(INK))/(PNK(INK+1)-PNK(INK))
IF(INA.NE.4) GO TO 49
INA=3
IF(NA.NE.PNA(4)) PRINT 48
48 FORMAT(* THE VALUE OF NA IS EXTRAPOLATED*)
49 FA=(NA-PNA(INA))/(PNA(INA+1)-PNA(INA))
IF(FS.LT.0.) PRINT 44
IF(FK.LT.0.) PRINT 46
*
*     LOAD ARRAY TO BE INTERPOLATED.
*
N=0
IO1=INO+1
ID1=IND+1
IS1=INS+1
IK1=INK+1
IA1=INA+1
DO 60 I5=INA,IA1
DO 60 I4=INK,IK1
DO 60 I3=INS,IS1
DO 60 I2=IND,ID1
DO 60 I1=INO,IO1
N=N+1
60 B(N)=A(NAME(I1,I2,I3,I4,I5))
*
*     INTERPOLATE.
*
DO 62 N=1,29,4
62 B(N)=(1.-FD)*(B(N)*(1.-FO)+FO*B(N+1))+FD*(B(N+2)*(1.-FO)+FO*B(N+3))
DO 64 N=1,25,8
64 B(N)=B(N)*(1.-FS)+FS*B(N+4)
DO 66 N=1,17,16
66 B(N)=B(N)*(1.-FK)+FK*B(N+8)
AREL=B(1)*(1.-FA)+FA*B(17)
68 CONTINUE
*
*     PRINT AREL, AVG I.
*
AREL=AMAX1(AREL,1.)
PRINT 75,AREL
75 FORMAT(* AREL=*,F8.3)
IF(IPARAM.NE.2HPH) GO TO 89
AVG I=0.3048*E/DT*EXP(-NA)*NK*NK/(AREL*PI*WIDTH*WIDTH)
PRINT 85,AVG I
85 FORMAT(* AVG. IRRADIANCE=*,F9.3,* KW/CM*,3H**2)
```

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03550 89 CONTINUE
03560 100 CONTINUE
03570 PRINT 8
03580 PRINT,* DO YOU HAVE ANOTHER RUN? *
03590 READ 1,MPARAM
03600 IF(MPARAM.EQ.2HMU.OR.MPARAM.EQ.2HSI) GO TO 10
03610 STOP
03620 END
```