(\*The following program is based on a global optimization algorithm, using for the numerical simulation of photon avalanche responses. Explanatory comments are added to the essential sections of the code. The software used is ***1stOpt 10.0*** from 7D-soft high technology Inc. The user interfaces are also added.\*)

**Variable**

t=[0:0.002:0.2],n1=1.83E21,n2=0,n3=0,n4=0,n5=0,n6=0,n7=0,n8=0;

*// Defining the initial population density of all the modeled energy levels for Tm3+ ions*

**LoopConstant**

powerex=[400000:4000:1000000];

*// Defining the variation range and step size of excitation power density in W cm-2*

**Constant**

factor=1,

crfactor=1,

GSAfactor=1,

ESAfactor=1,

*// Defining the coefficients to simulate the influence of different factors (ESA/GSA ratio, cross-relaxation, depopulation rate) on photon avalanche responses*

photonenergyof1064=1.87E-19, *//photon energy of each 1064 nm photon in Jole*

absorptioncrosssectionofGSA=GSAfactor\*7E-25, *//absorption cross-section for GSA process*

absorptioncrosssectionofESA1=ESAfactor\*7E-21, *//absorption cross-section for ESA1 process*

absorptioncrosssectionofESA2=ESAfactor\*7E-22,*//absorption cross-section for ESA2 process*

b31=0.1, *//brunching ratios of all depopulation process for excited states*

b32=1-b31,

b41=0.2,

b42=0.3,

b43=1-b41-b42,

b51=0.05,

b52=0.07,

b53=0.1,

b54=1-b51-b52-b53,

b61=0.3,

b62=0.1,

b63=0.45,

b64=0.12,

b65=1-b64-b63-b62-b61,

b71=0.36,

b72=0.46,

b73=0.02,

b74=0.08,

b75=0.07,

b76=1-b75-b74-b73-b72-b71,

b81=0.2,

b82=0.1,

b83=0.4,

b84=0.1,

b85=0.05,

b86=0.05,

b87=1-b86-b85-b84-b83-b82-b81,

w2=10000\*factor, *//depopulation rates of all excited states*

w3=100000\*factor,

w4=30000\*factor,

w5=100000\*factor,

w6=20000\*factor,

w7=20000\*factor,

w8=20000\*factor,

cr1=(5.4E-17)\*crfactor, *//cross-relaxation constants for all related cross-relaxation processes*

cr2=(8E-18)\*crfactor,

cr3=(8E-18)\*crfactor;

plot t[x], n4; *//to plot the population kinetics of the photon avalanche emitting level*

*// Defining the key parameters in photon avalanche dynamics process. GSA、ESA1、ESA2* are the //cross-sections of ground-state absorption and excited-state absorption of energy states for Tm3+ ions*. bij (i=3-8, j=1-8) denotes the emission branching ratio between state ni and nj. wi (i=2-8) represents the relaxation rates (including the non-radiative relaxation rate and radiative relaxation rate) of energy states for Tm*3+ *ion, respectively.*

**ODEFunction** *// The rate equations for each of the modeled energy states. Here ni (i=1-8) denotes the population density of the 3H6, 3F4, 3H5, 3H4, 3F3/3F2, 1G4, 1D2, 1I6 energy states of Tm3+ ion with a concentration of 15%.*

n1'=-n1\*powerex\*absorptioncrosssectionofGSA/photonenergyof1064-cr1\*n1\*n4+cr3\*n4\*n6+b81\*w8\*n8+b71\*w7\*n7+b61\*w6\*n6+b51\*w5\*n5+b41\*w4\*n4+b31\*w3\*n3+w2\*n2;

n2'=-n2\*powerex\*absorptioncrosssectionofESA1/photonenergyof1064+2\*cr1\*n1\*n4+cr2\*n4\*n6-w2\*n2+b32\*w3\*n3+b42\*w4\*n4+b52\*w5\*n5+b62\*w6\*n6+b72\*w7\*n7+b82\*w8\*n8;

n3'=n1\*powerex\*absorptioncrosssectionofGSA/photonenergyof1064-w3\*n3+b43\*w4\*n4+b53\*w5\*n5+b63\*w6\*n6+b73\*w7\*n7+b83\*w8\*n8;

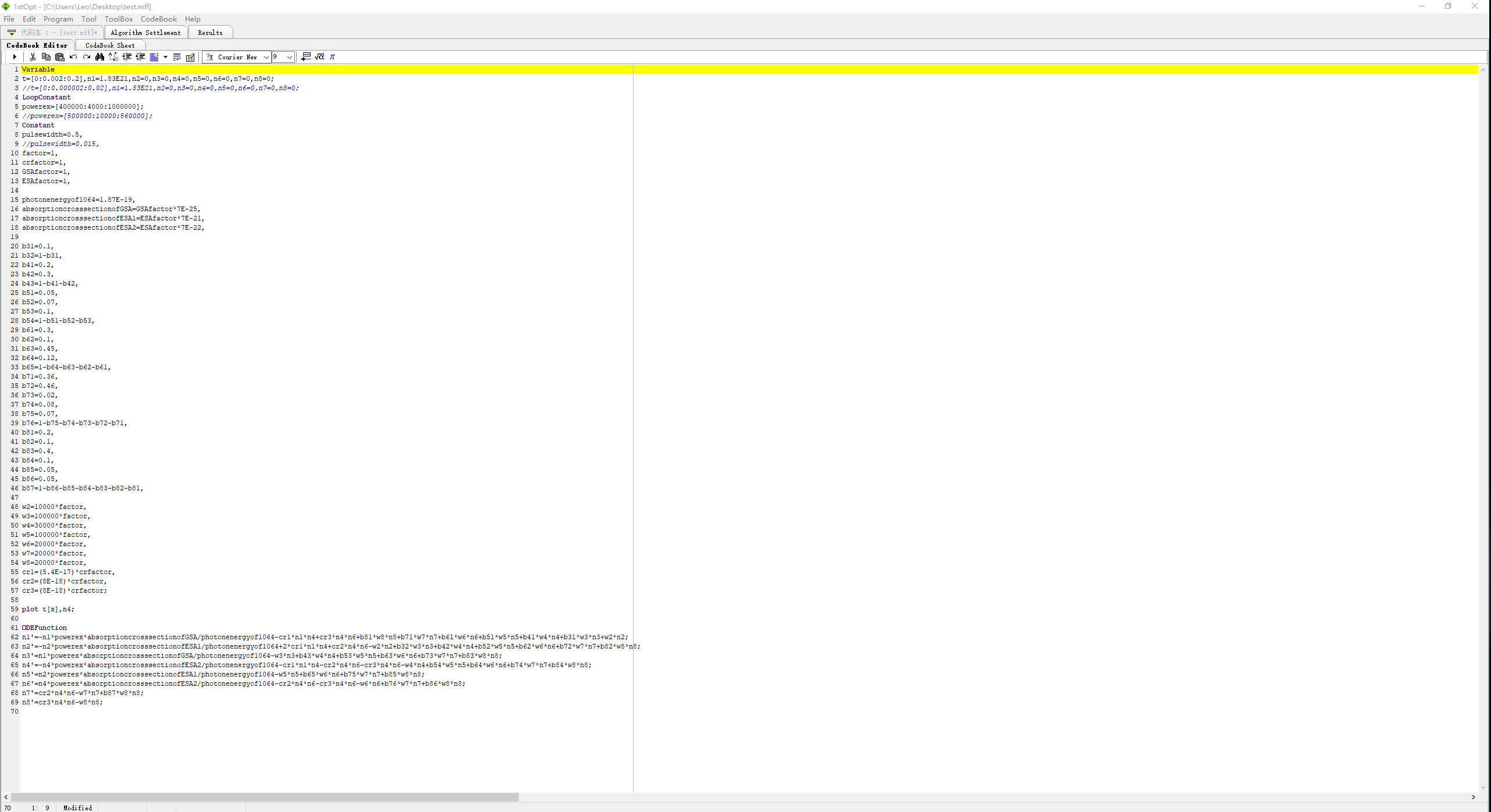
n4'=-n4\*powerex\*absorptioncrosssectionofESA2/photonenergyof1064-cr1\*n1\*n4-cr2\*n4\*n6-cr3\*n4\*n6-w4\*n4+b54\*w5\*n5+b64\*w6\*n6+b74\*w7\*n7+b84\*w8\*n8;

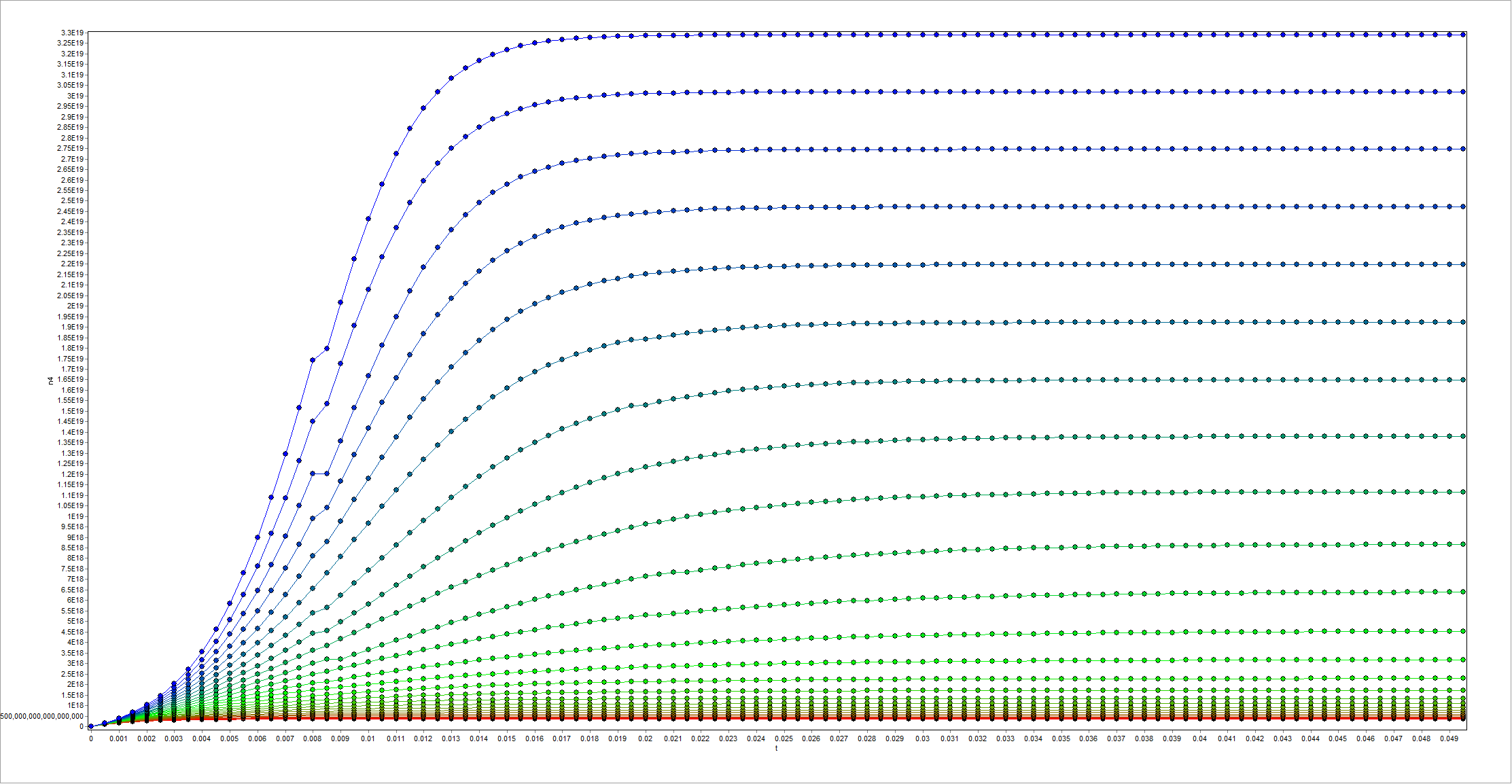
n5'=n2\*powerex\*absorptioncrosssectionofESA1/photonenergyof1064-w5\*n5+b65\*w6\*n6+b75\*w7\*n7+b85\*w8\*n8;

n6'=n4\*powerex\*absorptioncrosssectionofESA2/photonenergyof1064-cr2\*n4\*n6-cr3\*n4\*n6-w6\*n6+b76\*w7\*n7+b86\*w8\*n8;

n7'=cr2\*n4\*n6-w7\*n7+b87\*w8\*n8;

n8'=cr3\*n4\*n6-w8\*n8;

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