A

Abel inversion, 696, 743
absorption cross section, 161
acceleration of wafer stage, 33
acceleration time, 32
active plasma cleaning, 989
aerial-image microscope (AIM), 634
anomalous resistivity, 232
aperture function, 895
astron discharge, 459
atomic data modeling codes
  atomic structure calculations, 150
  CIV3, 114
  Cowan code, 62, 216, 693
  Cowan suite of codes, 151
  Flexible Atomic Code (FAC), 113, 114
  HULLAC, 114, 155, 316, 323, 349
  multiconfiguration Dirac-Fock (MCDF), 114, 316
  multiconfiguration Hartree-Fock (MCHF), 114, 315, 316
  random-phase approximation with exchange, 160
  self-consistent Dirac-Fock-Slater iteration, 114
  single-configuration Dirac-Fock (SCDF), 52
  single-multipole approximation, 114
  SUPERSTRUCTURE, 114
  time-dependent local density approximation (TDLDA), 160
  code DAVID, 160
  also see under plasma modeling, laser-produced plasma modeling
  applications of the EUV tube, 833
atomic data—tin
  energy levels, ionization potential, lines and transition probability, 353
  Sn VI, 121
  Sn VII, 117, 122
  Sn VIII, 117, 123
  Sn IX, 117, 126
  Sn X, 117, 131
  Sn XI, 117, 137
  Sn XII, 142
  Sn XIII, 144
  Sn XIV, 146
  Sn XV, 147
emissivity, 350
relative ion population in plasma, 155, 595
spectra
  classification, 117
  comparison experimental and theoretical, 118, 353
  experimental, 117, 118, 160, 183, 405
  recording, 113
  spectral lines table, 120
  theoretical, 116, 162, 236, 304, 323, 325
  theoretical absorption spectra of Sn I–IV, 162
time-gated and space-resolved spectra of Sn vacuum spark, 190
transition probabilities for Sn VI–XV, 116
atomic data—xenon
  absorption coefficients, 290
  benchmarking
    input data, 54
    output data, 55
electron-impact ionization cross section, 53
energy levels
  Xe VIII (q = 7), 71
  Xe IX (q = 8), 81
  Xe X (q = 9), 90, 353
  Xe XI (q = 10), 97
  Xe XIX (q = 17), 69
ionization energies all ionic stages, 52
  Xe (q < 7 or > 18), 54
  Xe VIII, 59
  Xe IX, 61
  Xe X, 63
  Xe XI, 64
  Xe XII, 65
  Xe XIII, 66
  Xe XIV, 66
  Xe XV, 67
  Xe XVI, 67
Xe XVII, 68
Xe XVIII, 68
Xe XIX, 69
ionization rate, Xe X ion, 227
ion fraction distribution versus electron temperature, 163, 302
outlook and future data needs, 56
oscillator strength Xe IX–XVIII, 151
photoionization cross sections, 53
spectra
  experimental, 51, 309, 552
  theoretical, 151, 224, 341
spectral lines
  Xe VIII, 75
data sources, 80
  Xe IX, 84
  Xe X, 93
  Xe XI, 102
  4d8-4d75p transitions, 150
  4p64dn-4p54dn+1+4dn-14f lines, 15
  Xe XIX, 111
Auger decay probabilities, 825
Auger electron spectroscopy (AES), 736, 1021
average-atom (AA) model, 226, 312
axially symmetrical discharges (ASDs), 179
AXUV-100 diode, 376, 613
beam dump, 463
beamlines, 842
bending-magnet (or dipole) radiation, 842, 845
Bennett relation, 180
BESSY II electron storage ring, 786
bias electronics, 776
Biberman-Holstein approximation, 225
Bloch-Gruneisen law, 234
Boltzmann kinetic equation, 236
bremsstrahlung radiation, 693
burst-mode operation, 376
capillary discharge, 248
EPRA MPP, 248
capillary Z-pinch, 505
  angular distribution, 513
  angular distribution monitor (ADM), 507
  collection optics, 458
  conversion efficiency (CE), 511
debris mitigation, 16, 385, 433, 515
designed head, 506
  dissipated energy, 512
Flying Circus (FC), 9, 701, 721
grazing-incidence collector, 517
  intermediate focus (IF) profile, 517
beam profile, 520
  comparison with models, 520
  images, 519
in-band image, 615
magnetic pulse compression generator, 428, 506
circuit diagram of the MPC generator, 507
power, 515
prepulse, 509
Schwartzschield collector, 517
spectra, Xe, 511
  stability, 512
  waveform, current, voltage and EUV signal, 509
  witness plate, 517, 1001
Zr/Si3N4 filter, 518
cleanliness of source, 28, 36
  joint requirements, 27
  coefficient of local emission and absorption, 210
  coherence factor, 37
collection angle, 897, 910
collection efficiency, 893, 899, 908
collector, 553, 590, 592, 598
coefficient of thermal expansion (CTE), 880
collection limits, 9
description, 6
electroforming, 881
erosion, 995
  and redeposition of material, 948
  observations in ETS, 998
  of Ru by Xe+, 951
  rates of materials, 1011
  rates of materials, flux independent, 1011
general considerations, 875
grazing angle collectors, 11, 876
design, 877
ellipsoidal mirrors, 877
  fabrication, 881
  hyperboloidal-ellipsoidal design, 878
  parabolic mirrors, 877
testing, 885
  Wolter type 1 design, 878
lifetime measurements, 19
  also see under various sources
  mandrel, 881
  coating, 882
    nickel deposition, 883
    fabrication, 881
  phase-shift optical interferometric measurement, 882
materials, 9, 926
measurements of reflectivity
  90% encircled energy widths (W90), 884
half energy widths (HEW), 885
mirror shell integration, 885
multilayer collectors, 9
off-axis imaging, 879
reflective coating, 879
reflectivity, 9, 880
dependence on roughness, 881
measured and calculated of Ru, 1021
requirements, 876
testing, 885
material testing, 932
reflectivity measurement setup, 887
trends and challenges, 890
collisional mixing (CM), 948
collisional-radiative equilibrium (CRE) model, 154, 216, 227, 287
component lifetime
also see lifetime under various sources
component degradation specs, 38
collector transmission, 10, 39
electrode transmission, 39
filter transmission lifetime, 39
multilayer transmission lifetime, 39
overall component degradation, 32
cost of ownership, 17, 39, 473, 574
consumables, 39
consumable cost, 40
estimation, 39
initial cost, 40
operating cost, 39
Coulomb explosion, 1035
Coulomb logarithm, 304
Cowan code, 62, 302
critical current, heavy-ion plasmas, 180
critical dimension control, 34, 35
error budget, 38
current crowbar, 253
Debye length, 744
Debye temperature, 234
deceleration time, 33
defect-mediated desorption (DMD), 1036
dense plasma focus (DPF), 253, 278, 373
angular distribution, 380
burst-mode operation, 376
collector, 386
conversion efficiency (CE), 376
debris mitigation and contamination studies, 385
dynamics, 255
lifetime limitations, 387
Mather-type DPF configuration, 374
modeling, 259, 278, 382
power, 376
power scaling, 387
pulsed-power development, 375
source size, 380
thermal management, 378
detailed term accounting (DTA), 314, 315, 352
diamondlike carbon (DLC), 802
dielectronic recombination, 51
diffusion coefficient, 971
diffusion length, 971
directed discharges, 459
discharge-produced plasma (DPP)
see
capillary discharge
capillary Z-pinch
dense plasma focus (DPF)
gas-discharge-produced plasma (GDPP)
hollow-cathode-triggered (HCT) plasma pinch discharge
pinch discharges
plasma capillary source
Star Pinch
Doppler broadening, 525
Doppler-broadened line, 210, 565
dose repeatability, 34, 35
dose stability, 684
Dulong–Petit law, 234
Index

E electrode obscuration effects, 899, 902
electrodes, 915, 926
carbon-based material (CBM), 923
efficiency, 39
erosion mechanism, 486, 922
lifetime, 19, 407, 423
also see under various discharge-produced plasma sources
materials, 926, 930
carbon-fiber composites (CFCs), 928
pseudo-alloys, 926
pyrolytic graphite, 928
refractory components, 927
porous-metal cooling, 15
testing, 932
copper, 917
tungsten, 917, 927
thermal response, 917
time dependence, 919
also see under various discharge-produced plasma sources
electron-based EUV sources, 823
angular distribution, 829
applications
  calibrations, 833
  transmission curve measurements, 836
Auger decay probabilities, 836
conversion efficiency (CE), 827
electron-induced characteristic emission, 824
EUV and soft-x-ray spectra, 828
EUV brightness, 831
EUV tube, 824
long-term stability, 831
power scaling, 831
Si L-edge Cherenkov emission, 824
silicon energy-level scheme, 827
silicon EUV spectrum, 826
source size, 829
tungsten spectrum, 836
electron beam ion trap (EBIT), 55, 154, 1037
electron-hydrodynamic approach, 233
electron plasma frequency, 304
electron storage rings
  see synchrotron radiation
electrostatic energy analyzer (ESA), 747, 966, 1017
electrostatic ion energy analyzer (ESIEA), 706
elementary discharge source (EDS), 178
ELSAC, 594
emission wavelength, 51
emitter materials, 421, 542
E-MON, 725
energy levels
  see atomic data
energy stability, 484
energy stability budget, 34
Engineering Test Stand (ETS), 649, 998
equilibrium radius, 188
erosion mechanisms, 922
escape factor, 209, 212
etendue
  acceptance factor, 417
calculation, 37, 416
coherence factor, 37
illumination system, 894
joint requirements, 28
magnification, 37
match, 10, 13
source, 36, 894
system, 910
Euler-Lagrange variables, 241
EUVL, 4, 27
  implementation challenges, 6
  scanners, utility requirements, 7
EUV sources
  see
discharge-produced plasma (DPP) sources
electron-based EUV sources
laser-produced plasma (LPP) sources
synchrotron radiation EUV sources
exposure time, 32
external electric circuit, 281
Extreme Ultraviolet Lithography System Development Association (EUVA), 607, 1016

F failure-mode and effect analysis (FMEA), 673
Faraday-cup ion probe (IP), 704
fast-ion characterization, 1016
fast-ion mitigation, 1022
figure of merit, 163
filter wheel, 778
flat-field spectrograph (FFS), 699
Flexible Atomic Code (FAC), 113
foil comb, 463
foil trap, 970
forbidden transitions, 51
frozen xenon droplets, 681
fuel source, 40
  see also under various sources
Fundamental Data Working Group (FDWG), 48
Flying Circus, 9, 701, 721, 777

G gas-discharge-produced plasma (GDPP), 414
collector, 423
collector lifetime, 434
  in situ cleaning procedures, 447
debris filter, 434
debris mitigation, 433
etendue, 416
etendue acceptance factor, 417
electrode lifetime, 427
electrodes, 423
fuel materials, 421
pinch effect, 418
pinch plasma, 418
plasma size, 444
porous-metal heat exchanger, 432
power, 438, 442, 445
power scaling, 441
pulse power, 427
integrated gate bipolar transistor (IGBT), 429
magnetic pulse compression generator, 428
magnetic switch, 429
pulse compression ratio, 429
pulse-to-pulse fluctuations, 437
thermal management, 421, 431
water-cooled electrode, 432
XTS, 435, 448
Z-pinch, 413
gas transmission, 10, 214, 387, 724
Sn DPP, 11
Xe DPP, 11
gated CMOS array, 680
gas transmission, 10, 214, 387, 724
Sn DPP, 11
Xe DPP, 11
gated CMOS array, 680
geometrical collection efficiency, 9
geometrical flux, 894
Gibbsian adsorption (GA), 948
Gibbsian segregation, 985
goniometer, 765
Granville-Phillips stable-ion gauge, 791
grazing angle collectors, 11, 876
grazing-incidence mirrors (GIMs), 946
gridded energy analyzer (GEA), 963
H
Hartree-Fock (HF) self-consistent-field
atomic model, 277
Hartree-Fock-Slater (HFS) approximation, 286
Hartree-Fock-Slater model, 227
Hartree-Fock-Slater quantum-statistical model, 237
Helmholtz–Lagrange invariant (HLI), 894
high-energy-density physics (HEDP), 224
highly charged ions (HCIs), 48, 1034
atomic physics of, 149
high-temperature insulator ceramics, 929
high voltage (HV), 526
high-voltage electrode (HVE), 492
historical overview of metrology development and standardization, 721
hollow-cathode triggered (HCT) plasma pinch discharge, 395, 396
collection efficiency, 404
converter lifetime, 407
converter materials, 408
conversion efficiency (CE), 404
debris, 407
design, 401
electrode lifetime, 407
ignition phase, 397
lifetime, 399
modeling, Monte Carlo model, 398, 400
multiborehole configuration, 403
pseudospark discharge, 396, 459
thermal load, 407
I
imaging spectrometer, 811
implicit scheme, 242
inertial Z pinch, 456
insertion magnets, 842
in situ cleaning procedures, 447
integrated energy stability, 28
integrated gate bipolar transistors (IGBTs), 429
interaction of materials with charged particles and components testing (IMPACT), 946
Interferometric Data Evaluation Algorithms (IDEA), 697
intermediate focus (IF), definition of, 29
International Radiation Detectors (IRD, AXUV-100G), 613
intrinsic conversion efficiency (ICE), 482
ion acoustic velocity, 305
ionization chamber, 773
ionization energy, see atomic data
ionization fraction, 977
ion velocity, 209
insulator ceramics, 929
beryllium oxide, 929
candidate materials, 928
corundum, 929
nitrides of aluminum, 929
nitrides of boron, 929
properties, 928
pyrolytic boron nitride (PBN), 929
testing, 932
zirconium dioxide, 929
Interferometric Data Evaluation Algorithms (IDEA), 697
interferometry, measurement of electron density, 698
inverse bremsstrahlung, 351, 542
inverse bremsstrahlung absorption (IBA), 304, 691
irradiation stability, 802
Japanese Ministry of Economy, Trade and Industry (METI), 607, 1016
jj coupling, 50, 293, 327
Joule dissipation, 234
Joule heating, 181
K
K-edge wavelength, 788
kink-mode instabilities, 246
Kirchhoff’s law, 319
Kirkpatrick-Baez glancing-incidence optical system, 856
L
Landé interval rule, 288
Langdon effect, 351
Larmor radius, 1022
lasers
acousto-optical (AO) switching, 587
beam quality, 547, 588
beta laser, 682
CO₂ laser, 541, 547
diffraction limit (DL), 673
diode-pumped solid state (DPSS) laser, 595
electro optical (EO) switching, 566
excimer, 17, 541
GEKKO XII laser system, 353
master oscillator (MO), 670
master oscillator–power amplifier (MOPA), 17, 547, 586, 608, 670
multibeam laser focusing, 588
multiplexing, 16, 546
Nd:YAG, 154, 541, 608, 651, 670, 739, 762
Starlase, 566
power oscillator–power amplifier (POPA), 586
power requirements
pulsed CO₂, 17
excimer, 17, 546
power rollover, 672
pump diode current, 672
pulse length, 16
Q-switched lasers, 154
requirements, 5
solid state lasers, 673
spatially and temporally multiplexed laser modules, 563
spatial multiplexing, 568, 578
ELSAC prototype, 578
SHINE module, 595
spider configuration, 596
spiderlike side attack, 589
stimulated Brillouin scattering (SBS), 670
temporal resolution of pulse, 672
wall-plug efficiency, 8
Yb:YAG, 550
laser-produced plasma (LPP)
angular distribution, 380, 513, 554, 573, 580, 829, 899, 903, 906
collector, 11, 607
also see under collector
deformable mirror, 610
sputtering, 434, 639
collector lifetime, 407, 530
conversion efficiency (CE), 347, 551, 579, 585, 630, 656
dependence on wavelength, 356
xenon and tin slab targets, 261, 341, 670, 702
cost of ownership, 574
debris emission
ion, 638, 704
mechanism, 693
ML degradation, 709
particle, 707
debris mitigation, 690
design parameter, 342, 704
dose control, 591
economical viability, 557
emission efficiency, 261
emission spectrum
from water-methanol droplets, 622
from xenon, iodine, and tin, 623
etendue, 553, 614, 633
etendue transmission factor, 539
integration into ETS, 653
laser intensity requirements, 564
laser parameters, 564
modular LPP source, 577
optical thickness, 622
optimum plasma temperature, 564
power, 16, 343, 537, 538, 650, 670
tin droplet, 263
tin targets, 149
xenon droplet, 264
scaling, 441, 471, 556
source size, 484, 553, 633, 829, 911
spatially and temporally multiplexed, 563
stability, 579, 608, 628, 630, 650, 653, 672, 679
target materials, 622
thermal management, 378, 600
laser-produced plasma (LPP) modeling, 299
average-atom (AA) model, 226, 312
AVERROES, 316, 318
collisional-radiative codes, 51, 152, 314, 351
collisional-radiative model (CRM), 352
dependence on wavelength, 356
deviation of wavelength, 356
dependence on wavelength, 356
downstream, 470, 471
ELSAC prototype, 578
SHINE module, 595
spider configuration, 596
spiderlike side attack, 589
stimulated Brillouin scattering (SBS), 670
temporal resolution of pulse, 672
wall-plug efficiency, 8
Yb:YAG, 550
laser-produced plasma (LPP)
angular distribution, 380, 513, 554, 573, 580, 829, 899, 903, 906
collector, 11, 607
also see under collector
deformable mirror, 610
sputtering, 434, 639
collector lifetime, 407, 530
conversion efficiency (CE), 347, 551, 579, 585, 630, 656
dependence on wavelength, 356
xenon and tin slab targets, 261, 341, 670, 702
cost of ownership, 574
debris emission
ion, 638, 704
mechanism, 693
ML degradation, 709
particle, 707
debris mitigation, 690
design parameter, 342, 704
dose control, 591
economical viability, 557
emission efficiency, 261
emission spectrum
from water-methanol droplets, 622
from xenon, iodine, and tin, 623
etendue, 553, 614, 633
etendue transmission factor, 539
integration into ETS, 653
laser intensity requirements, 564
laser parameters, 564
modular LPP source, 577
optical thickness, 622
optimum plasma temperature, 564
power, 16, 343, 537, 538, 650, 670
tin droplet, 263
tin targets, 149
xenon droplet, 264
scaling, 441, 471, 556
source size, 484, 553, 633, 829, 911
spatially and temporally multiplexed, 563
stability, 579, 608, 628, 630, 650, 653, 672, 679
target materials, 622
thermal management, 378, 600
laser-produced plasma (LPP) modeling, 299
average-atom (AA) model, 226, 312
AVERROES, 316, 318
collisional-radiative codes, 51, 152, 314, 351
collisional-radiative model (CRM), 352
dependence on wavelength, 356
downstream, 470, 471
ELSAC prototype, 578
SHINE module, 595
spider configuration, 596
spiderlike side attack, 589
stimulated Brillouin scattering (SBS), 670
temporal resolution of pulse, 672
Index

detailed configuration accounting (DCA) method, 313
detailed term accounting (DTA), 352
Dirac equation, 316
Dirac-Fock equations, 317
GRASP, 351
Hartree-Fock approximation with relativistic extensions (HFR), 317
HULLAC code, 316, 323, 349
hydro code, MED, 103, 306
hydrodynamic Lagrangian code CHIVAS, 311
laser coupling and interaction, 303
Layzer complexes, 318
magnetohydroradiative-dynamic research (MHRDR), 382
modified semi-empirical method (MSEM), 310, 699
multiconfiguration Dirac-Fock (MCDF), 316
multiconfiguration Hartree-Fock (MCHF), 316
Poisson equation, 398
power balance model, 343
radiation hydrodynamic code, 348
radiation transfer models, 318
screened hydrogenic model (SHM), 348
SCO, 325
SCROLL, 316
SCAALP code, 318
spin-orbit split array (SOSA), 314
super transition array (STA), 315
Thomas-Fermi (TF) model, 312
laser-produced plasma (LPP) targets, 544, 620
droplet solid, 611
tin, 266
water, 309, 698
electron density, 698
emission spectrum, 310
xenon, 18, 264, 545, 581, 680
filament, xenon, 571, 681
gas puff, xenon, 261
glass targets, tin-doped, 156
high-density clusters, xenon, 651
jet aerosol spray jet, 675
heat shield, 676
xenon, 264, 545, 620, 624, 651, 1005
liquid jet droplet formation distance, 626
evaporative cooling, 626
freezing, 626
jet stabilization through nozzle heating, 628
xenon, 674
mass limited, 12, 546, 651, 690
tin-doped liquid droplet target, 691
spectra of, 701
water ice, 150
planer targets
Ge and Re, 150
tin, 572, 703
xenon, 678
recycling system
xenon, 571, 594, 599
slab xenon and tin, 261
spherical targets, 308
xenon and tin, 263
Lawrence Livermore National Laboratory (LLNL), 856
LCR circuit, 243
lead zirconium titanate (PZT), 753
LED, pulsed, 680
Lichtleitwert, 894
liquid-droplet target, 621
liquid-jet target, 621
liquid-spray target, 621
liquid xenon spray jet, 657
LiNbO₃ crystal, 697
linear density trajectory, 189
line edge roughness (LER), 13
line emission coefficient, 695
line width, 699
local thermodynamic equilibrium (LTE), 211, 306, 614, 699
low-energy ion scattering spectroscopy (LEISS), 950
LS coupling, 50, 293
LS-coupling approximation, 288
M
macrophoton, 284
magnetic insulation, 457
magnetic lenses, 842
magnetic switch, 429
magnetohydrodynamic (MHD) processes, 277, 279
magnetohydroradiative-dynamic research (MHRDR), 382
Mather-type DPF configuration, 374
Maxwell equation, 231
mean free path, 971
metrology, 759
2% bandwidth mirrors, 729
acceptance angle, 722
atomic force microscopy (AFM), 737, 1021
Auger depth profiling, 676, 1000
Auger electron spectroscopy (AES), 736, 1021
AXUV-100 photodiode response curve, 724
calibration, 760, 785
calibration procedure, 723
calorimeters, 935
electron diagnostics, 742
electron temperature measurement, 745
electrostatic analyzer
  with TOF spectrometer, 745, 747
  with quadrupole mass filter, 750
electrostatic ion energy analyzer (ESIEA), 706
E-Mon energy detector, 725
EUV multilayer telescope, 727
Faraday-cup ion probe (IP), 704, 1010
fast-ion characterization, 1016
Flying Circus, 721
  measured quantities, 728
  source performance data, 726
gridded energy analyzer (GEA), 963
historical overview of development, 721
inband imaging, 615
inband source-size measurement, 723
interferometry, 726
ion diagnostics, 745
ion energy analyzer (IEA), 704
Langmuir probes, 742, 1001
low-energy ion scattering spectroscopy (LEISS), 950
microchannel plate (MCP), 738, 966
mirror imaging systems, 738
neutral-atom detectors, 752
pinhole cameras, 738
plasma diagnostics, 735
plasma frequency measurement, 744
plasma imaging, 738
polarization interferometry, 742
pyroelectric calorimeter wafer, 753
quartz-crystal microbalance (QCM), 737, 963
quartz-crystal-microbalance–dual-crystal unit (QCM-DCU), 950
scanning electron microscopy (SEM), 737
scanning tunneling microscopy (STM), 1037
secondary-ion mass spectroscopy (SIMS), 737
Schlieren imaging, 740
shadowgraphs, 738
surface accumulators, 736
Thomson parabola spectrometer (TPS), 706, 750
Thomson scattering, 744
time-of-flight (TOF), 704
TOF spectrometry, 745, 747
transmission electron microscopy (TEM), 1021
transmission of various components, 724
witness plates, 736
x-ray photoelectron spectroscopy (XPS), 736, 950, 1021
XUV diagnostics, 722
microchannel plate (MCP), 185, 738, 966
microexposure tool (MET), 633
micropinches, 187
  equilibrium radius, 188
Mie diffusion, 580
mitigation techniques, 957, 969, 976, 985
Mo/Be, 29
monochromator, 765
Monte Carlo-based radiation transport (MCRT), 284
MOPA architecture, 671
Mo/Si, 29
MTBF, 39
MTTR, 39
multichannel plate (MCP), 746
multilayer mirror (MLM), 29
  lifetime
    see lifetime under various sources
Mo/Be, 29
Mo/Si, 29
  reflectivity, 13, 39, 724
  reflectivity of 11-mirror system, 30
roadmap for improvement, 864
N
National Synchrotron Light Source (NSLS), 859
neck instabilities, 179, 246
  development scenario, 183
  experimental observation, 185
non-LTE, 224, 306, 313
nonequilibrium parameter, 239
non-LTE, 228
  normal-incidence reflectance
    of a Mo/Si multilayer (ML), 852
    of clean Al, 852
numerical aperture (NA), 895
numerical diffusion, 241
O
object field size, 895
obscuration effects
  anode, 968
electrode, 899, 902
Ohm’s law, generalized, 231
opacity effects, 150, 154–155, 162, 164, 167, 361, 382
opacity project database, 699
operating costs, 40
optical depth, 210, 230, 319
optically thick lines, radiance of Ne and Xe lines, 211
optical thickness, 291, 565
out-of-band (OOB) radiation, 11, 201, 216, 634, 704
overhead time, 32

P

particle-in-cell method, 236
Paschen curve, 177, 233, 397, 402
Pease-Braginskii current, 180
petals, 1004
optical photographs, 1007
phase-space volume, 894
photodiode, 899
photodiode calibration, 773
photon bundle, 284
Physikalisch-Technische Bundesanstalt, 724
pinch discharges, 477
Bennett equilibrium, 478
conversion efficiency (CE), 482
electrode erosion, 486
electrode system, 494
  effective electrode surface, 488
excimer-laser-initiated pinch discharge in Sn, 495
fuel, Sn vapor, 491
high-voltage electrode (HVE), 492
intrinsic conversion efficiency (ICE), 482
lifetime, 486
power, 482
rotating-disk electrode (RDE), 498
rotating multi-discharge-unit (RMDU), 489
Si3N4, 488
source size, 484
spectra, 484
spouting pinch discharge, 480
stability, 484
pulse-to-pulse repeatability, 485
vapor shielding, 488
Z pinch, 478, 482
Z-pinch configurations, 479
pinch effect, 175, 418, 478
  formation of pinch columns, 176
gas-puff pinch, 177
theta pinch, 175
X pinch, 177
Z pinch, 175
pinch plasma, 418
pinhole camera, 738, 899, 904
Planckian radiator, 202
  ideal, 203
  spectral efficiency of, 202
Planck mean absorption coefficient, 321
Planck's law, 201, 319, 541
plasma, axial velocity of, 248
plasma capillary source, 523
  ablative capillary discharges, 526
  conversion efficiency (CE), 531
Doppler broadening, 525
gas-filled capillaries, 524
lifetime, 530
modeling, 524
polyacetal, 524
polyacetal capillary, 527
  EUV spectra, 532
PVC capillary, 527
spectrum of a discharge with argon, 525
Kr and Xe spectra in the EUV region, 527
unresolved transition array (UTA), 529
power, 529
plasma-column energy balance, 180
plasma compression, 3D, 248
plasma critical density, 541, 565, 696
plasma focus discharge, 177
plasma gun, 933
diagnostics, 935
hydrogen plasma, 934
plasma modeling
ANGARA-5, 236
completely conservative scheme, 241
discrete-ordinate method (DRT), 283
distorted-wave approximation (DWA), 227
HEIGHTS-EUV package, 277, 918
implicit scheme, 242
Lax-Friedrich formulation, 277, 918
MHD description, 218
Monte Carlo model, 398, 400
multigroup radiation transport model, 244
Newton's method, 242
plasma and radiation and solid-material interactions, 234
RMHD code Z*, 236
spectral ray-tracing postprocessing, 245
TERM, 237
THERMOS, 188, 237
tool for source optimization, 215
total variation diminishing (TVD) scheme, 277
TRIM, 1011, 1034
Z* code, 223
ZETA, 236
Z accelerator, 236
plasma outflow, 185
plasma sheath, noncylindrical, 253
plasma sound speed, 565
Poco graphite, 676
poly methyl methacrylate (PMMA), 859
  absorption coefficient, 859
positioning stability, 36
potential energy sputtering, 1033
power scaling, 387, 831
preferential sputtering (PS), 948
preionization
  influence of, 252
  processes, 232
prepulse, effect of, 165
projection algorithm, 899, 900
PROTO I, 179
pseudorandom number, 399
pseudospark discharge, 396
pulse compression ratio, 429
pulsed power, 427
pulsed response of Si photodiodes, 775
pulsed-power development, 375
pyroelectric calorimeter, 753

Q
quality of imaging (critical dimension control), 34
quantum efficiency, 206, 770, 775
quartz-crystal microbalance (QCM), 737, 963
quartz-crystal-microbalance–dual-crystal unit (QCM-DCU), 950
quasi-neutrality, 232
quasi-stationary approximation, 228

R
Racah algebra, 315
radiation diffusion, 321
radiation-enhanced diffusion (RED), 948
radiation-hardened Si photodiodes, 776
radiation-induced segregation (RIS), 948
radiation loss, 181
radiation transfer equation, 229
radiation transport, detailed, 280
Monte Carlo-based radiation transport (MCRT), 284
radiation transport equation (RTE), 283
radiative collapse (RC), 175, 180, 247
stability of trajectory, 190
Z-pinch, 175
radiative cooling time, 209
radiative decay rate, 188
radiative magnetohydrodynamics (RMHD), 224
effective conservative schemes, 241
radiative yield, factors that influence, 208
rates of
absorption and emission in spectral lines, 226
Auger effect (autoionization) and dielectronic capture, 226
collisional deexcitation, 188, 212, 226
collisional excitation, 209, 226
excitation and ionization, 207
ionization and three-body recombination, 226
photoionization and radiative recombination, 226
Rayleigh’s criterion, 874
Rayleigh-Taylor instability, 250, 610
ray tracing, 898, 910
recombination radiation, 693
recycling system, 571
reflectometry, 765, 836
repeller field, 712
repetition frequency, requirements, 28
requirements estimation, 33
residual gas analyzer (RGA), 571
resist
line edge roughness (LER), 13
sensitivity performance, 14
sensitivity requirements, 31
resistivity, 287
resonance lines, 62
of rare gases for calibration, 787
RMHD code Z*, 236
Rosseland mean absorption coefficient, 321
rotating multi-discharge-unit (RMDU), 489
rotating-disk electrode (RDE), 498

S
satellite lines, effect of, 360
scan speed, 35
scanning electron microscopy (SEM), 737
scanning time, 32
scanning tunneling microscopy (STM), 1037
Schlieren imaging, 740
Schottky barrier devices, 777, 798
Schwartzschild optic, 857, 863
screened hydrogenic model (SHM), 348
second-harmonic generator (SHG), 697
secondary-ion mass spectroscopy (SIMS), 737
self-trapped exciton (STE), 1036
shadowgraphs, 738
shot-to-shot reproducibility, 190
see also stability under various sources
Si L-edge Cherenkov emission, 824
Si$_3$N$_4$, 488
Si$_3$N$_4$/Nb filter transmission, 724
SiC, 506
silicon EUV spectrum, 826
skin depth, 235
Slater-Condon parameter, 153
slit width, 35
snowplow model, 176, 255, 269
Sommergjen phase-shifting diffraction interferometer, 856
source angular distribution, 899, 903, 906
also see under various sources
source diameter, 909
source distribution, 897, 899, 902, 905
source efficiency, 199
collection, 200
driver, 200
plasmas, 200
radiator, 200
spectral, 200
source, EUV
  see EUV sources
source length, 909
source performance measurements
  also see under metrology
  2% bandwidth mirrors, 9
  accuracy, 9
  cross-calibration, 9
  factors influencing collection, 9
  factors influencing requirements, 13
  Flying Circus (FC), 9
  intermediate focus (IF) measurements, 9
  measurement methods, 9
source pinch size, 909
source power
  also see under various sources
determination, 898
  performance status, 726
    Li DPP, 16
    Li LPP, 19
    Sn DPP, 15
    Sn LPP, 18
    Xe DPP, 15
    Xe LPP, 18
  requirement estimation, 203
source power, collectible, 897
source power scalability, 200
source repeatability, 35
  number of pulses, 35
  repetition rate, 35
  source-induced repeatability budget, 36
source size, 13, 187, 191, 909, 911
  effect on collection efficiency, 910
  also see under various sources
source technology
  future outlook, 20
  joint requirements, 27
    changes in, 28
    etendue of source output, 28
    EUV power, 28
    integrated energy stability, 28
    maximum solid angle input, 28
    repetition frequency, 28
    source cleanliness, 28
    spectral purity, 28
    wavelength, 28
  limits, 10
  performance status, 5
  potential showstopper, 5
source volume, 894, 897, 898, 908
  projection, 900
source, utility requirements, 7
spectra
  see under atomic data and under various sources
spectral efficiency
  of a Planck radiator, 202
tin, 214
xenon, 214
spectral line width of an isolated line, 310, 699
spectral purity, 28, 38
  joint specs, 28
  also see under OOB
spectral purity filter (SPF)
technology, 9
  transmission, 11
spectral radiance, 201, 209
spectral radiation energy density, 230, 238
spectrographs, 807
  flat-field spectrograph (FFS), 699
  transmission grating spectrograph (TGS), 699
  variable-spacing (Harada) grazing-incidence grating, 699
spray jet, 1009
sputter erosion, 457
sputtering yield, 1033
copper, 951, 962
tungsten, 962
Spitzer conductivity, 181
Stark broadening, 211
Star Pinch, 453
  astron discharge, 459
  spectra of Ar, 461
  beam dump, 463
  collector optics, 433–434
  colliding-beam plasma source, 461
  conversion efficiency (CE), 466
  cost of ownership, 473
  directed discharges, 459
  discharge cathode, 458
  first wall, 454
  foil comb, 463
  fuel materials, 469
  gas barrier, 458
  inertial Z-pinch, 456
  lifetime, 468
  magnetic insulation, 457
  multiple-channel hollow-cathode discharge, 460
  plasma expansion time, 457
  plasma size, 467
  plasma stability, 467
  pseudospark discharge, 459
  power, 466
  scaling, 471
  sputter erosion, 457
  sputter removal coefficient, 456
  thermionic cathodes, 458
  wall material, 455
  Stefan-Boltzmann law, 201, 209
  sublimation of metal, 235
  superconfiguration code SCO, 325
surface accumulators, 736
SXUV-type diode, 799
synchrotron radiation sources, 760, 786, 841
  BESSY II electron storage ring, 786
  basic parameters, 790
  electrical substitution radiometer (ESR), 774, 786, 795
  EUV direct undulator beamline, 791
  basic parameters, 793
  imaging spectrometer, 811
  inband power meter, 808
photodiode
  calibration, 773
  irradiation stability, 802
  linearity, 805
  long-term stability, 801
  self-calibration, 800
  spectral responsivity, 797
reflectometer, 792
  spectral detection efficiency, 812
  of E-spec®, 815
spectrally filtered tools, 807
spectrographs, 807
spectral radiant power, 789
Synchrotron Ultraviolet Radiation Facility (SURF III), 761
  absolute cryogenic radiometer (ACR), 774
  calibration of EUV radiometry tools, 777
  Flying Circus, 777
  detector characterization, 769
  quantum efficiency, 770
  quantum efficiency spatial uniformity, 772
  quantum efficiency stability, 771
  speed, 772
infband EUV power instrumentation, 764
ionization chamber, 773
monochromator, 765
output spectrum of SURF III, 761
photodiode
  calibration, 773
  linearity, 772
  out-of-band response, 773
  pulsed response, 775
  pulsed response saturation, 776
  responsivity, 776
reflectivity map, 768
reflectometer optical throughput, 767
reflectometry, 765
transmission curve, Zr filter, 769
overview
  applications in lithography, 849
  beamlines, 842
bending-magnet (or dipole) radiation, 842
  EUV radiation, 845
  EUV imaging, 858
  EUV interferometry, 855
  focusing magnets (quadrupoles), 842
  injector, 842
  insertion magnets, 842
  Kirkpatrick-Baez glancing-incidence optical system, 856
  Lorentz contraction factor, 842
  magnetic lenses, 842
  phase-shifting point-diffraction interferometer (PSPDI), 856
  reflectivity measurements of Al, Ir, and ML, 853
  reflectometer, 855
  scanning-mirror illuminator, 861
  Sommargren phase-shifting diffraction interferometer, 856
  steering magnets (sextupoles), 842
  survey of current facilities, 848
  undulator radiation, 844, 846
  wiggler radiation, 844, 848

T
  tape target, 621
  TERM, 237
  thermal extraction, 15
  dissipation of electrical energy, 186
  also see thermal management under sources
  thermal instability, 235, 250
  thermal management, 378, 600
  THERMOS, 188, 237
  throughput model, 31
  acceleration of wafer stage, 33
  acceleration time, 32
  deceleration time, 32
  field exposure time, 33
  field number, 32
  overhead time, 32
  relationship of throughput and stage acceleration, 33
  scanning time, 32
  wafer exposure time, 32
  tin
  see under atomic data and fuel for various sources
  Thomson parabola spectrometer (TPS), 706, 750
  Thomson scattering, 744
time-of-flight (TOF), 704
  TOF spectrometer, 745, 747
toroidal mirror, 765
total variation diminishing (TVD), 918
total variation diminishing (TVD) scheme, 277
transition energy, 51, 349
transmission electron microscopy (TEM), 1021
transmission grating spectrograph (TGS), 699
TRIM, 1011, 1034
turbo molecular pumps, 655

U
ultrafast electronic excitation, 1036
undulator radiation, 844, 846
unresolved transition array (UTA), 151, 156, 211, 302, 352, 529
intensity, 156
variation of peak position with atomic number, 156
usable radiation, 899, 903, 908
utility requirements, EUV sources, 7

V
vacuum spark, 115
low inductance discharges, 177
vapor shielding, 488
Virtual National Laboratory (VNL), 996

W
wafer dose sensor (WDS), 663
wafer throughput model, 31
wall material, 455
width of an isolated line, 310, 699
wiggler radiation, 844, 848
Wollaston prism, 696
Wolter objective, 590
Wolter type 1 design, 9, 415, 423, 590, 592, 878–879, 890

X
x-ray photoelectron spectroscopy (XPS), 736, 950, 1021
xenon
see under atomic data and various sources
xenon recycler, 599
XTS, 435
XUV diagnostics, 722

Y
YAG:Ce crystals, 729

Z
Z accelerator, 236
Z-pinches, 413
Z-pinches configurations, 479
Z_{eff}, 181
Z* code, 223
ZETA, 236
zippering effect, 187, 191