

Contents

Contributors

Preface

ix

xi

Part 1. Papers from the Tenth International Conference on Charged Particle Optics edited by P.W. Hawkes and M. Berz

| | |
|---|-----------|
| 1. Planar multi-reflecting time-of-flight mass-spectrometer of a simple design | 3 |
| Seitkerim B. Bimurzaev | |
| 1. Introduction | 3 |
| 2. Orthogonal ion accelerator with a non-uniform two-dimensional symmetrical field | 4 |
| 3. Three-electrode two-dimensional electrostatic mirror | 8 |
| 4. Planar multi-reflecting time-of-flight mass-spectrometer of a simple design | 11 |
| 5. Conclusion | 12 |
| Acknowledgments | 12 |
| References | 13 |
| 2. Generalization of paraxial trajectory method for the analysis of non-paraxial rays | 15 |
| Shin Fujita | |
| 1. Introduction | 15 |
| 2. Canonical mapping and optical parameters | 18 |
| 3. Electron source characterization | 21 |
| 4. Generalized paraxial trajectory method | 23 |
| 5. <i>G-optk</i> program | 27 |
| 6. Discussion | 30 |
| 7. Conclusions | 33 |
| Acknowledgments | 33 |
| References | 33 |
| 3. Test and characterization of a new post-column imaging energy filter | 35 |
| Frank Kahl, Volker Gerheim, Martin Linck, Heiko Müller, Richard Schillinger, Stephan Uhlemann | |
| 1. Introduction | 35 |
| 2. Optics design | 38 |

| | |
|---|------------|
| 3. Characterization | 45 |
| 4. Performance | 53 |
| 5. Conclusion and outlook | 65 |
| Appendix A Energy resolution and number of resolved image points | 66 |
| Acknowledgments | 68 |
| References | 68 |
| 4. Electron optics for a multi-pass transmission electron microscope | 71 |
| Marian Mankos, Stewart A. Koppell, Brannon B. Klopfer, Thomas Juffmann, Vladimir Kolarik, Khashayar Shadman, Mark Kasevich | |
| 1. Introduction | 71 |
| 2. Electron-optical layout of a multi-pass transmission electron microscope | 72 |
| 3. Summary | 85 |
| Acknowledgments | 85 |
| References | 85 |
| 5. A simulation program for electron mirrors using Boundary Element Method | 87 |
| Eric Munro, Haoning Liu, Catherine Rouse, John Rouse | |
| 1. Introduction | 88 |
| 2. Important applications of electron mirrors | 88 |
| 3. Simulation methods for electron mirrors | 90 |
| 4. Advantages of our new BEM software | 91 |
| 5. Theory of our new BEM software | 91 |
| 6. Data specification | 95 |
| 7. A worked example | 98 |
| 8. Plans for future work | 103 |
| 9. Summary | 109 |
| Acknowledgments | 109 |
| References | 109 |
| 6. An algorithm for simulating the geometric optics of charged particle instruments | 111 |
| Khashayar Shadman | |
| List of abbreviations | 112 |
| 1. Introduction | 112 |
| 2. The standard algebraic algorithm | 115 |
| 3. Power series representation of a function | 119 |
| 4. The array equation | 127 |
| 5. Application of the algorithm to a round lens | 135 |
| 6. Validation of the algorithm | 145 |
| 7. Conclusion | 156 |

| | |
|--|-----|
| Appendix A Generalization of the algorithm | 156 |
| Appendix B Compound series expansions | 158 |
| Appendix C Numerical integration | 165 |
| Appendix D Equation of motion for a round lens | 169 |
| Appendix E Primary nonlinear coefficients | 173 |
| References | 178 |

Part 2. The Nano-Aperture Ion Source

| | |
|--|------------|
| 7. Introduction to focused ion beams, ion sources, and the nano-aperture ion source | 181 |
| Leon van Kouwen | |
| 1. Why ion beams are fun | 181 |
| 2. A closer look at FIB systems | 189 |
| 3. The nano-aperture ion source | 197 |
| List of symbols | 211 |
| Acknowledgment | 211 |
| References | 212 |
| 8. Nano-fluidic flow in the nano-aperture ion source | 217 |
| Leon van Kouwen | |
| 1. Introduction | 217 |
| 2. Flow model | 218 |
| 3. Conclusion | 231 |
| List of symbols | 232 |
| Acknowledgment | 233 |
| References | 233 |
| 9. Optics of ion emission from the nano-aperture ion source | 237 |
| Leon van Kouwen | |
| 1. Introduction | 238 |
| 2. Source properties | 238 |
| 3. Emission in a uniform field | 244 |
| 4. Emission from a realistic geometry | 254 |
| 5. Brightness from phase space evolution | 267 |
| 6. Conclusion | 272 |
| Appendix A | 273 |
| List of symbols | 273 |
| Acknowledgment | 274 |
| References | 275 |

10. A model for ion-neutral scattering in the nano-aperture source 277

Leon van Kouwen

| | |
|--|-----|
| 1. Introduction | 278 |
| 2. Ion-neutral interaction | 278 |
| 3. Monte-Carlo implementation | 282 |
| 4. Model validation | 286 |
| 5. An effective mean free path | 290 |
| 6. Neutral particle-density distribution | 297 |
| 7. Monte-Carlo ray tracing | 300 |
| 8. Conclusion | 302 |
| List of symbols | 303 |
| Acknowledgment | 304 |
| References | 304 |

11. Ion emission simulations of the nano-aperture ion source 307

Leon van Kouwen

| | |
|---|-----|
| 1. Introduction | 307 |
| 2. Ion-induced surface charge | 308 |
| 3. Monte-Carlo ray tracing | 315 |
| 4. Ion-electron interactions | 329 |
| 5. Conclusion | 337 |
| Appendix A The extended two-particle approximation and the slice method | 338 |
| List of symbols | 340 |
| Acknowledgment | 341 |
| References | 341 |

12. Processes in the ionization volume of the nano-aperture ion source 343

Leon van Kouwen

| | |
|--------------------------------------|-----|
| 1. Introduction | 343 |
| 2. Calculation method | 346 |
| 3. Estimates of the beam composition | 350 |
| 4. Conclusion | 352 |
| List of symbols | 353 |
| Acknowledgment | 354 |
| References | 354 |

Index 357