This specification provides a concise summary of the main features of the programme and the learning outcomes that a typical student might reasonably be expected to achieve and demonstrate if he/she takes full advantage of the learning opportunities that are provided. This specification provides a source of information for students and prospective students seeking an understanding of the nature of the programme and may be used by the College for review purposes and sent to external examiners. More detailed information on the learning outcomes, content and teaching, learning and assessment methods can be found in the course handbook online at http://www3.imperial.ac.uk/controlledquantumdynamics/admissions. The accuracy of the information contained in this document is reviewed by the College and may be checked by the Quality Assurance Agency.

1. **Awarding Institution:** Imperial College London
2. **Teaching Institution:** Imperial College London
3. **External Accreditation by Professional / Statutory Body:** N/A
4. **Name of Final Award:** MRes
5. **Programme Title:** Controlled Quantum Dynamics
6. **Date of production / revision of this programme specification:** 08/2013
7. **Name of Home Department:** Physics
8. **Name of Home Faculty:** Natural Sciences
9. **UCAS Code** (or other coding system if relevant): N/A
10. **Relevant QAA Subject Benchmarking Group(s) and/or other external/internal reference points**
    Physics, Astronomy and Astrophysics

11. **Level(s) of programme within the Framework for Higher Education Qualifications (FHEQ)**

| Master’s (MSc, MRes, MBA, PG Diploma and PG Certificate etc.) | Level 7 |

12. **Mode of Study**

One year Full-Time

13. **Language of Study:** English

14. **Educational aims/objectives of the programme**

The programme aims/objectives are to:
The formal aim of the MRes in Controlled Quantum Dynamics (CQD) is to teach the students the core theoretical concepts and experimental methods of the controlled quantum dynamics of small numbers of quantum systems, their multi-particle coherence and entanglement properties, and of methods for
their preparation, control and read-out to the level enabling doctoral study in the field or for a technical career outside academia.

This aim is fulfilled via the following formal objectives. The MRes in CQD will:

• attract well-qualified Bachelor level students and provide an intellectually challenging multi-disciplinary degree programme, equipping the students with the technical knowledge and skills necessary for postgraduate studies in controlled quantum dynamics;
• provide high quality advanced education in the relevant scientific skills, both theoretical and experimental, beyond Bachelor level within an environment with considerable teaching and research experience in the field;
• give students the experience of undertaking a major, individual project and reporting the results in a full scientific report and presentation;
• give students training in appropriate research methods;
• develop students’ skills of communication, both written and oral, to specialised and non-specialised audiences;

15. Programme Learning Outcomes

1. Knowledge and Understanding

1. The fundamental laws and principles of the appropriate aspects of quantum mechanics, along with their theoretical analysis and experimental realisation (some at the forefront of the discipline)
2. Research skills training, for either theoretical or experimental projects.
3. How to analyse and develop an in depth knowledge of relevant research issues and a critical evaluation of the scientific literature in a given topic of study.
4. How to plan, execute and report the results of an extended theoretical and/or experimental project

The learning outcomes are achieved by a combination of lectures courses, experiments, project work and exercises. Students are encouraged to use their unsupervised time to undertake further study outside lectures and to develop team working skills when working on the exercises.

The project will either be theoretical or experimental in nature. All projects, however, require students to research the appropriate scientific literature and use that to guide further work. As the MRes is associated with the CDT in CQD, the project work will be carried out with research groups associated with the CDT.

The extended individual project work includes breaking down complex, real scientific problems to design experiments or theoretical models and validate them by experiment or theoretical or computational analysis.

Mathematical and computational tools will be widely used on the course, with a lecture course on the 1st term on the most important tools. Appropriate training will be given for other tools used for specific tasks.

The programme has access to a wide range of Professional Skills courses via GSEPS, where presentation, communication and team-working skills are learned.

2. Skills and other Attributes

Intellectual Skills

1. Apply knowledge of physical principles, mathematical and computational techniques to scientific problems in the field.
2. Use mathematical techniques to construct and analyse problems in CQD;
3. Demonstrate the ability to plan, undertake, and report on a programme of original work; including the planning and development of theoretical and/or experimental programmes of research, the
analysis and interpretation of experimental results, and validation of the models involved.

4. Research and examine critically the scientific literature.

- Lectures, computational methods course and training on instrumentation (where appropriate), research skills training and project work are used to enable students to apply the theoretical knowledge gained from the taught course material to theoretical or practical problems.
- The project will require significant prior research, planning and analysis to successfully undertake the original research in the allotted time.

**Practical Skills**

1. plan and execute safely a series of experiments or computations, including the identification and use of specialist equipment;
2. use laboratory methods or computer-based tools to generate data;
3. analyse results, determine their strength and validity, and make recommendations;
4. prepare technical reports;
5. give technical presentations;
6. use the scientific literature effectively;

- Practical skills are taught by the combination of the computational methods and instrumentation course and project work. In particular, for those students with a significant experimental component to their project, the work requires students to design and undertake experiments, analyse the data (including a discussion of the errors) and prepare assessed technical reports and presentations.
- There will be a full briefing on safety matters before any experimental work.

**Professional Skills Development**

1. Problem-solving skills;
2. Investigative skills;
3. Communication skills;
4. Analytical skills;
5. IT skills;
6. Personal skills:

- A supervised written research project will require the students to prove their analytical and investigative skills by critiquing and applying a body of research to a real world problem.
- Research reports, presentations and publications of students’ work test students’ communication skills, supported by workshops on writing and presentation skills.
- All data analysis and modelling is undertaken using the appropriate IT tools, and computational work will require using specialist scientific packages. Training is given where necessary. All research reports and presentations are prepared with appropriate IT tools.
- Personal skills are developed using Graduate School courses on communication and presentations skills; team working and career skills are developed using workshops and group tasks throughout the programme. Students will be directed to attend the workshops most appropriate to their existing skill set.
- Communication skills to non-expert audiences and the public will be developed in an outreach project which requires the entire cohort to collaborate to develop an outreach lecture on the activities of the CQD CDT.

In addition to the training embedded in the programme, the Graduate School runs a Professional Development Skills programme for Master’s students. The programme, consisting of the “MasterClass” workshops and e-learning modules, aims to help students develop the skills needed both in their academic studies and in obtaining and progressing in their future careers. The Careers Advisory Service also provides training and support for students on career options, job seeking and interviews.

16. **The following reference points were used in creating this programme specification**
• Subject benchmarking information for Physics, Astronomy and Astrophysics.
• Student Handbook for Course.

17. Programme structure and features, curriculum units (modules), ECTS assignment and award requirements

<table>
<thead>
<tr>
<th>Year one</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Term one:</strong> The students study four compulsory lecture courses; Quantum Optics (6 ECTS), Introductory Quantum Information Theory (6 ECTS), Quantum Physics and Chemistry of Cold Matter (5 ECTS) and Tools for CQD (6 ECTS) – this course continues in term 2. The students are also required to take an appropriate lecture course from another Masters course or a level 4 MSci course, in either Term 1 or Term 2 (6 ECTS). In certain circumstances, depending upon the individual student’s background, other non-level 4 UG courses may be taken for credit at the discretion of the course co-ordinator. The students are encouraged to take appropriate Graduate School courses to improve their professional skills.</td>
</tr>
<tr>
<td><strong>Term Two:</strong> Examinations are held for the Mathematical Methods and Instrumentation course and the Introductory Quantum Information Theory course at the start of term. The students study two more compulsory courses; Experimental Realisations of Controlled Quantum Dynamics (5 ECTS) and Advanced Quantum Information Theory (5 ECTS). The students work with the CDT Outreach Officer on an Outreach project, where the students work in teams to prepare a lecture on the research carried out in the CDTs, suitable for an undergraduate audience (5 ECTS).</td>
</tr>
<tr>
<td><strong>Term Three:</strong> The students start the experimental or theoretical work for their research projects. At the start of During the term, students sit the Quantum Optics examination and the examination of the optional courses they studied.</td>
</tr>
<tr>
<td>For Master’s courses – June –Sept: During the third term and the summer the students will work full time on their individual research project (46 ECTS).</td>
</tr>
</tbody>
</table>

18. Support provided to students to assist learning (including collaborative students, where appropriate).

Departmental/Course Induction Programme:

The first activity on the course is an introductory lecture where the structure, academic and administrative requirements of the course is explained and details given about the support services, including English language support, available within the College.

A detailed course handbook, covering the above information in considerable detail is available at the introductory lecture and on the course website.

Students receive a Departmental welcome pack, which includes details on the College support services (i.e., counselling, health and safety and professional skills).

A briefing on general safety is compulsory for all students. There are also compulsory briefings on laboratory safety and laser safety (if needed).

Departmental Facilities:
The academic support for the students comes primarily from the course lecturers, the academic staff who act as demonstrators in the practical work classes and project supervisors. The number of students on the MRes is normally around 10 - 15 and this is a small enough group that they are actively encouraged to go directly to course lecturers with academic questions on an informal basis. Specialised training, for example, maths is available from other staff in the Department.

Students undertake a major research project during their course of study; there are several members of staff allocated to each student as a supervisor or assessor.

**Departmental/Course Feedback Policy:**

All continually assessed coursework is returned with comments and a letter grade. Examination grades are given to the students (after a meeting of the examiners) and they are encouraged to discuss the results with the course supervisor or the cohort mentor.

**Welfare and Pastoral Care:**

College student welfare services are the responsibility of the Director of Student Affairs who manages the Head of the Student Counselling Service, the Senior Disability Officer, the College Tutors and the Hall Wardens. The Director of Student Affairs acts as liaison between the College and the College Health Centre (NHS) and the Chaplaincy and works closely with the ICU Deputy President (Welfare) to enhance welfare, advice and support.

One member of academic staff acts as the course tutor and is responsible for welfare and for personal tutoring of the cohort. The course tutor will meet with each student on an individual basis once a term to discuss their progress, but is available for consultation at all other times. Another member of academic staff will act as a cohort mentor. This role is concerned with team-building and social activities.

**The Library**

There are libraries at all Imperial College campuses; with print collections, PCs, study space and other amenities. The Library has extensive electronic resources, including electronic databases, electronic books and full text electronic journals. Students are able to search for electronic resources, using the on-line library catalogue and web pages, and access them from anywhere on and off campus.

**English Language Support Programme**

The English Language Support Programme (ELSP) offers classes, the majority of which are free of charge, to students and members of Imperial College London who are not native speakers of English.

**19. Criteria for Admission**

The minimum qualification for admission will normally be a First Class Honours degree in Physics or a relevant scientific discipline from a UK academic institution or an equivalent overseas qualification.

All applicants must satisfy the College’s English proficiency requirements.

**20. Processes used to Select Students**

Upon receipt into the Department, all new applications are considered by a panel of academics from the CDT in CQD with specified member of staff co-ordinating the process. The panel decides which of the applicants to interview and a set of interviews are arranged to be held on consecutive days in March.

In many cases, further information may be sought (from referees, for example). Applicants close to College are invited for an interview, but telephone interviews may be used for applicants further away. The interviewing panel is comprised of three members of academic staff of the CDT in CQD. The panel meets after the interviews and decides upon which students to offer places. Some offers will be
turned down by the applicants, in which case the panel decides whether to make further offers to students on a reserve list.

21. Methods for Evaluating and Improving the Quality and Standards of Teaching and Learning

a) Methods for review and evaluation of teaching, learning, assessment, the curriculum and outcome standards:

The external examiner system and Boards of Examiners are central to the process by which the College monitors the reliability and validity of its assessment procedures and academic standards. Boards of Examiners comment on the assessment procedures within the College and may suggest improvements for action by relevant departmental teaching Committees.

At programme level, the Head of Department has overall responsibility for academic standards and the quality of the educational experience delivered within the department.

The Faculty Studies Committees and the Graduate School Master’s Quality Committees review and consider the reports of external examiners and accrediting bodies and conduct internal routine reviews of programmes. The Quality Assurance and Enhancement Committee conducts external periodic reviews at departmental level. Regular reviews ensure that there is opportunity to highlight examples of good practice and ensure that recommendations for improvement can be made.

Most of the College’s undergraduate programmes are accredited by professional engineering and science bodies or by the General Medical Council. Accreditation provides the College with additional assurance that its programmes are of an appropriate standard and relevant to the requirement of industry and the professions. Some postgraduate taught courses are also accredited.

b) Committees with responsibility for monitoring and evaluating quality and standards:

The Senate oversees the quality assurance and regulation of degrees offered by the College. It is charged with promoting the academic work of the College, both in teaching and research, and with regulating and supervising the education and discipline of the students of the College. It has responsibility for approval of changes to the Academic Regulations, major changes to degree programmes and approval of new programmes.

The Quality Assurance and Enhancement Committee (QAEC) is the main forum for discussion of QA policy and the regulation of degree programmes at College level. The QAEC develops and advises the Senate on the implementation of College policies and procedures relating to quality assurance, enhancement and internal audit of quality and arrangements necessary to ensure compliance with national and international frameworks and codes of practice relating to academic standards, quality assurance and enhancement.

The Faculty Studies Committees and the Graduate School Master’s Quality Committees are the major vehicle for the quality assurance of undergraduate / Master’s courses respectively. Their remit includes: setting the standards and framework, and overseeing the processes of quality assurance, for the areas within their remit; monitoring the provision and quality of e-learning; undertaking reviews of new and existing courses; noting minor changes in existing programme curricula approved by Departments; approving new modules, changes in module titles, major changes in examination structure and programme specifications for existing programmes; and reviewing proposals for new programmes, and the discontinuation of existing programmes, and making recommendations to Senate as appropriate.

The Faculty Teaching Committees maintain and develop teaching strategies and promote inter-departmental and inter-faculty teaching activities to enhance the efficiency of teaching within Faculties. They also identify and disseminate examples of good practice in teaching.

The Physics Departmental Postgraduate Masters Course Committee has responsibility for the approval of minor changes to course curricula and examination structures and approves
arrangements for course work. They also consider the details of entrance requirements and determine departmental postgraduate student numbers. There are student representatives from the Department’s postgraduate taught courses. The Faculty Studies Committees and the Graduate School Postgraduate Quality Committees receive regular reports from the various Departmental Teaching Committees.

Within the CDT in Controlled Quantum Dynamics there are two committees that oversee quality assurance for the teaching. One is the course committee management board which meets at least once a term fortnightly. A student representative is elected to serve on this committee board and is responsible for feeding back any concerns the students may have. This committee looks after all the day to day activities of the CDT. The other important committee is the Advisory Panel. This is a panel of internal and external experts whose role it is to define the curriculum and maintain standards.

c) Mechanisms for providing prompt feedback to students on their performance in course work and examinations and processes for monitoring that these named processes are effective:

Examination results are fed back to students (with a letter grade) after the examinations have been reviewed by the internal examiners.

Practical work associated with the instrumentation course is assessed by a mixture of continuous assessment and laboratory write-ups.

For the project there is an assessed literature review and project plan, which will be submitted at the start of the second term. There is also an assessed interim review at the start of the third term.

d) Mechanisms for gaining student feedback on the quality of teaching and their learning experience and how students are provided with feedback as to actions taken as a result of their comments:

Students are invited to participate in surveys so that student feedback on the College and its courses can be obtained and used to enhance provision. External surveys in which students participate include:

- National Student Survey (NSS)
- Postgraduate Research Experience Survey (PRES)
- International Student Barometer (ISB)

Internal surveys include:

- SOLE (undergraduate student online evaluation exercise)
- PG SOLE (Master’s student online evaluation exercise)
- TOLE (tutor online evaluation exercise)

Staff-Student committees are the primary arenas for staff-student engagement at a departmental level. Staff-student committees are run slightly differently according to the size and UG:PG ratio of the department. Most departments have separate committees for undergraduates and postgraduates. A range of issues are discussed from SOLE and PG SOLE reports, external examiner reports and curriculum changes to practical issues, such as the availability of computers and pastoral care. Staff-Student Committees elect a Chair each year, which could be either a member of staff or a student. If the Chair is a member of staff, the Deputy Chair should be a student, and vice versa. The Chair will liaise with the department and students to agree an agenda for the meeting in advance.

e) Mechanisms for monitoring the effectiveness of the personal tutoring system:

This is managed through interactions between the student representative and the course committee. It will also be monitored by asking a relevant question on the autumn and spring term questionnaires.
f) Mechanisms for recognising and rewarding excellence in teaching, research supervision, pastoral care and supporting the student experience:

Staff are encouraged to reflect on their teaching, in order to introduce enhancements and develop innovative teaching methods. Each year College awards are presented to academic staff for outstanding contributions to teaching, pastoral care, supporting the student experience or research supervision. A special award for Teaching Innovation, available each year, is presented to a member of staff who has demonstrated an original and innovative approach to teaching. Nominations for these awards come from across the College and students are invited both to nominate staff and to sit on the deciding panels.

g) Staff development priorities for this programme include:

- Active research programme in physics
- Early in the probation period, lecturers attend an initial series of five workshops on teaching and learning
- Probationary lecturers are assigned a mentor who monitors and advises them on teaching
- New staff are required to take the College CASLAT learning and teaching certificate before completing probation
- Staff are appraised annually
- Staff are encouraged to attend College courses on teaching and learning and on professional development
- Graduate Teaching Assistants attend a workshop on demonstrating, and receive training on their particular teaching activity
- Staff are encouraged to join the Higher Education Academy (HEA)
- Staff are encouraged to attend meetings of the Institute of Physics Higher Education Group and the HEA

22. Regulation of Assessment

a) Assessment Rules and Degree Classification:

The Pass Mark for Master’s level programmes is 50%.

Examiners have the discretion to award a result of merit or distinction to candidates who have fulfilled the requirements for the award of the Master’s degree as specified in the Examination Regulations. Postgraduate Diplomas and Postgraduate Certificates are unclassified and are pass/fail only.

In order to be awarded a result of merit, a candidate must achieve at least 60 per cent in each element; in order to be awarded a result of distinction, a candidate must achieve at least 70 per cent in each element.

Where appropriate, a Board of Examiners may award a result of merit where a candidate has achieved an aggregate mark of 60% or greater across the programme as a whole AND has obtained a mark of 60% or greater in each element with the exception of one element AND has obtained a mark of 50% or greater in this latter element.

Where appropriate, a Board of Examiners may award a result of distinction where a candidate has achieved an aggregate mark of 70% or greater across the programme as a whole AND has obtained a mark of 70% or greater in each element with the exception of one element AND has obtained a mark of 60% or greater in this latter element.

Further information is available in the Academic and Examination Regulations.

The marking scheme for this programme is available at:

http://www3.imperial.ac.uk/controlledquantumdynamics/admissions

in the Course Handbook.
b) Processes for dealing with mitigating circumstances:

The College’s Extenuating Circumstances Affecting Academic Performance: Policy and Procedures makes provision for Boards of Examiners to use their discretion where extenuating circumstances are independently corroborated and are judged by the advisory panel to be of sufficient severity to have substantially affected performance.

c) Processes for determining degree classification for borderline candidates:

For Master’s programmes: Candidates should only be considered for promotion to pass, merit or distinction if their aggregate mark is within 2.5% of the relevant borderline. Nevertheless, candidates whom the Board deems to have exceptional circumstances may be considered for promotion even if their aggregate mark is more than 2.5% from the borderline. In such cases the necessary extra marks should be credited to bring the candidate’s aggregate mark into the higher range. Detailed records of all decisions should be recorded in the minutes of the meeting of the Board.

d) Role of external examiners

The external examiner system and Boards of Examiners are central to the process by which the College monitors the reliability and validity of its assessment procedures and academic standards. External examiners’ primary duties are to ensure that the standard of the College’s degrees is consistent with that of the national sector; to ensure that assessment processes measure student achievement rigorously and fairly and that the College is maintaining the threshold academic standards set for its awards in accordance with the frameworks for higher education qualifications and applicable subject benchmarks statements. External examiners gather evidence to support their judgement through the review of course materials, approval of draft question papers, assessment of examination scripts, projects and coursework, and in some instances, through participation in viva voce and clinical examinations. External examiners are members of Boards of Examiners and participate in the determination of degree classifications and student progress.

External examiners submit their reports to the Provost. The reports are scrutinised by the Vice-Provost (Education) and by the Registry QA team to identify any points of concern. These are then referred to the Head of Department and Chairman of the Board of Examiners, with a request to comment on the points raised and to explain how any concerns will be addressed. The reports and departmental comments are subsequently considered by the relevant Faculty Studies Committee or Graduate School Master’s Quality Committees, which may seek further assurances from a department on the resolution of a particular problem. The Committees will also consider examples of good practice raised by the external examiners. Following consideration of the reports, the Registry provides feedback to external examiners. From 2012-13 external examiner reports, and the departmental responses to them, are available on the College’s intranet.

23. Indicators of Quality and Standards

- Favourable comments by External Examiners.
- High proportion of students achieving a high degree classification.
- High proportion of MRes graduates continuing to PhD research in the CDT.
- Independent review of the quality of the educational provision of the Physics Department by the Quality Assurance Agency subject review process in 1998 achieving an excellent grading of 22 out of a maximum 24 points

24. Key sources of information about the programme can be found in

- Postgraduate Prospectus, Imperial College of Science, Technology & Medicine (available online www.imperial.ac.uk)
- Postgraduate Training in Physics at Imperial College (available online http://www3.imperial.ac.uk/physics/admissions/pg/msc/)
- MRes Course Handbook