Advanced Quantum Field Theory

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60 hours: 17 Lectures (34 hours) and 13x2 hours of practical training

1. **Space-time symmetries.** O(3) and $SU(2)$ groups; Lorentz group and representations. Scalar, spinor, vector fields. Poincare group and field representations.
2. **Classical theory of free fields.** Action principle and Noether theorem. Dynamical invariants (scalar, vector, Maxwell, Dirac).
3. **Quantum theory of free fields.** Canonical quantization of scalar and spinor fields. Massive vector field. Electromagnetic field. Coulomb gauge. Covariant quantization.
4. **Discrete symmetries;** Discrete transformations and CPT theorem.
5. **Gauge fields and gauge principle;** Gauge invariance. Global and local phase invariance. The gauge principle. Local non-Abelian symmetry.
6. **Canonical quantization of non-Abelian gauge theories;** The problem with non-Abelian gauge theories. Unitarily.
7. **Path integral quantization;** Scalar field theory model. Perturbative evaluation of the path integral. Euclidean formulation. Effective potential. Critical phenomena.
8. **Path integral quantization of gauge theories.** Faddeev - Popov method.
9. **Spontaneous symmetry breaking.** Degenerate ground state in QFT and NR many body systems. SSB and Nambu - Goldstone theorem. Higgs-Kibble mechanism in gauge theories. SSB and superconductivity.
10. **Multiparticle systems and second quantization.** Occupation number space. Bosons and Fermions. Fermi energy. Interacting electron gas, Phonons.
11. **Superconductivity and superfluidity :**Many-body electron systems BCS states. Meissner effect. Many-body boson system. Condensation and Superfluidity.
12. **Interacting fields.** Evolution operator and scattering matrix. Perturbation theory, Dyson expansion. T-products, Wick theorems.
13. **Perturbation theory**. Green's functions . Feynman diagrams. Scalar model, QED.
14. **Elementary processes:** Cross-sections for $A + B \to C + D$, $A \to B + C$. Basic two-body scattering in QED.
15. **Radiative corrections.** Higher order diagrams and renormalization. Electron self energy.
16. **Anomalous magnetic moment and Lamb shift.** Divergent integrals. Regularization. Vertex function. Photon propagator. Wave function renormaliztion.
17. **Basic renormalization in QED.** Ward identities. Combination of all divergent terms. Finite radiative corrections. The running coupling constant.

[1]. I. Aitchison; An informal introduction to gauge field theories (Cambridge University Press 1984)
[2] N.N.Bogoliubov, D.V.Shirkov; Introduction to the theory of quantized fields. (John Wiley & Sons, N.Y. 1980)

[3] B.Desai; Quantum mechanics with basic field theory (Cambridge University Press) 2010
[4] L.D. Faddeev and A.A. Slavnov, Gauge Fields: An Introduction To Quantum Theory, 2-nd ed. (Frontiers in Physics).
[5] M. Kaku; Quantum field theory: A modern Introduction; (Oxford University Press 1993)
[6] M.Maggiore; A modern introduction to quantum field theory (Oxford University Press 2005)