EUPROMETA – 29th Doctoral School on Metamaterials,
7-11 December, 2015 – Ruka, Finland

Fundamentals of Metamaterial Electromagnetics
School Program

7 December – Monday

Hour	Topic	Lecturer
08:30 – 08:45	**Participant registration**	
08:45– 09:00	**Opening and introductory information**	
09:00 – 09:45	**Basics of metamaterials – Part I** General introduction to metamaterials (definitions, some history). Basics: Maxwell equations, constitutive relations, wave equations, plane waves, wave numbers.	**Prof. Ari Sihvola**
09:45 – 10:00	**Coffee break**	
10:00 – 11:00	**Basics of metamaterials – Part II** Complex material responses, anisotropy, chirality and nonreciprocity, bianisotropy. Dispersion: Constitutive relations in time domain, causality and Kramers–Kronig conditions. Basic dispersion models: Lorentz model, Drude model, Debye model.	**Prof. Ari Sihvola**
11:00 – 12:00	**Introduction of topics for research mini-projects**	
12:00 – 13:00	**Lunch (Restaurant Piste)**	
13:00 – 14:45	**Basic topologies of metamaterial inclusions** Polarizability and single-particle response . Basic topologies of metamaterial inclusions. Wire media: Electromagnetic properties of wire lattices, circuit model, Drude behaviour, spatial dispersion. Split rings: Electromagnetic response of small conducting rings, circuit model, Lorentz behavior, bianisotropy. Limitations at high (optical) frequencies.	**Prof. Sergei Tretyakov**
14:45 – 16:30	**Glögi* break and poster session**	
16:30 – 17:30	**Setting up student groups for working on mini-projects**	
17:30– 18:00	**Experimental demonstration**	**Prof. Silvio Hrabar**
18:00 – 19:00	**Self-study**	

*Glögi is traditional Finnish warm mulled wine drank especially during Christmas time. Non-alcoholic.

8 December – Tuesday

Hour	Topic	Lecturer
09:00 – 10:45	**Effective medium modeling** From a single particle response to medium properties. Maxwell Garnett homogenization, Bruggeman homogenization. Exotic and extreme mixing cases (epsilon-near-zero background, negative-index inclusions, etc.)	**Prof. Ari Sihvola**
10:45 – 11:00	**Coffee break**	
11:00 – 12:00	**Working on research projects with the teachers**	
12:00 – 16:00	**Lunch (Restaurant Piste) and ski break / self-study**	
16:00 – 17:45	**Materials with exotic constitutive parameters** Negative material parameters, physical limitations. Backward waves, negative refraction, surface-mode resonances on interfaces between two isotropic media, operational principle of the perfect lens.	**Prof. Sergei Tretyakov**
17:45– 18:15	**Experimental demonstration**	**Prof. Silvio Hrabar**
18:15 – 19:00	**Self-study**	

9 December – Wednesday

Hour	Topic	Lecturer
9:15 – 10:00	**Bus tranport to Oulanka National Park (departure point in front of Hotel RukaVillage)**	
10:00 – 12:30	**Social event in Oulanka National Park and bus back to Ruka**	
13:00 – 14:00	**Lunch (Restaurant Colorado)**	
14:00 – 15:45	**Basics of metasurfaces** Definitions, surface impedance, frequency and spatial dispersion (dependence of the surface impedance on the frequency and on the propagation constant along the surface), surface waves, pass- and stop-bands. Leaky waves, their excitation and use in metasurface antennas.	**Prof. Stefano Maci**
15:45 – 16:00	**Coffee break**	
16:00 – 17:45	**Basics of plasmonics** Fundamentals of optical properties of metals, plasmonic resonance of small particles, surface plasmon polaritons, fundamentals of surface waves on interfaces, surface plasmon polaritons on metal surfaces, excitation and propagation of surface plasmons, comparisons with surface waves on high-impedance surfaces and metasurfaces in general. Main ideas of metatronics.	**Prof. Nader Engheta**
17:45 – 18:15	**Experimental demonstration**	**Prof. Silvio Hrabar**
18:15 – 19:00	**Self-study / free time**	
19:00 –	**School dinner (Restaurant Les Alpes)**	

10 December – Thursday

Hour	Topic	Lecturer
09:00 – 10:45	**Introduction to active and nonreciprocal metamaterials** Why we need active and nonreciprocal structures, examples of desired functionalities. Stability issues. Various physical principles behind nonreciprocal response (magnetized ferrites, active elements, parametric systems), examples of proposed devices.	**Prof. Silvio Hrabar**
10:45 – 11:00	Coffee break	
11:00 – 12:00	**Working on research projects with the teachers**	
12:00 – 16:00	Lunch (Restaurant Rukan Kuksa) and ski break / **self-study**	
16:00 – 17:45	**Overview of the current status and prospects of research on metamaterials and metasurfaces**	**Prof. Nader Engheta**
17:45 – 18:15	**Experimental demonstration**	**Prof. Silvio Hrabar**
18:15 – 19:00	**Self-study**	

11 December – Friday

Hour	Topic	Lecturer
09:00 – 10:00	**Student seminar**	
10:00 – 10:20	Coffee break	
10:20 – 11:20	**Student seminar, cont.**	
11:20 – 11:35	**Closing**	
12:10	**Departure to the airport**	

Map of the center of Ruka showing locations relevant to the course