

## One-dimensional $XY$ model of magnetoelectric in the presence of an energy current

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The spin-1/2  $XY$  chain model of magnetoelectric carrying an energy flux is studied using the Lagrange multiplier method [1]. The magnetoelectric coupling is described within the Katsura–Nagaosa–Balatsky mechanism [2]. Using the Jordan–Wigner transformation the problem is reduced to the Hamiltonian of free spinless fermions and can be solved exactly. We investigate the effect of the field  $\lambda$  driving the current of energy: the phase diagram in the  $(\lambda, \text{magnetic field})$ ,  $(\lambda, \text{electric field})$ , and  $(\text{magnetic field}, \text{electric field})$  planes are constructed and analysed at different model parameters.

1. T. Antal, Z. Rácz, and L. Sasvári, Phys. Rev. Lett. **78** (1997) 167.
2. H. Katsura, N. Nagaosa, and A. V. Balatsky, Phys. Rev. Lett. **95** (2005) 057205.