Isochronal Synchrony and Bidirectional Communication with Delay-Coupled Ikeda Ring Lasers

Brian Zhou (Caltech)

Prof. Rajarshi Roy

Nonlinear Optics Group

INSTITUTE FOR RESEARCH IN ELECTRONICS & APPLIED PHYSICS

TREND FAIR

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Introduction

- Synchronization of chaotic systems leads to applications in communications and control – it is a useful phenomenon.

Introduction

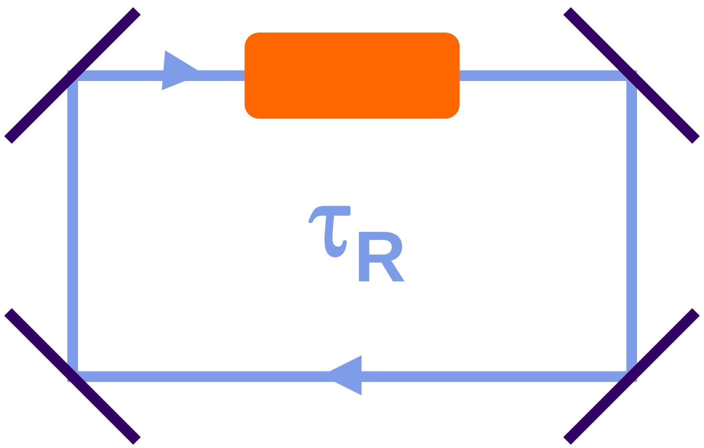
- We propose a model system for simultaneous, bidirectional communication.
- Mutually delay-coupled systems:
  - Synchronize with delay (achronal) rather than isochronal.
  - Erratic switching between leader and follower.
- Reliable bidirectional communication requires isochronal synchrony.

Ikeda Ring Lasers (IR)

- Simplest model of fiber ring lasers.
- No spatial dependence. Consider single point along ring (just before amplifying medium), then:

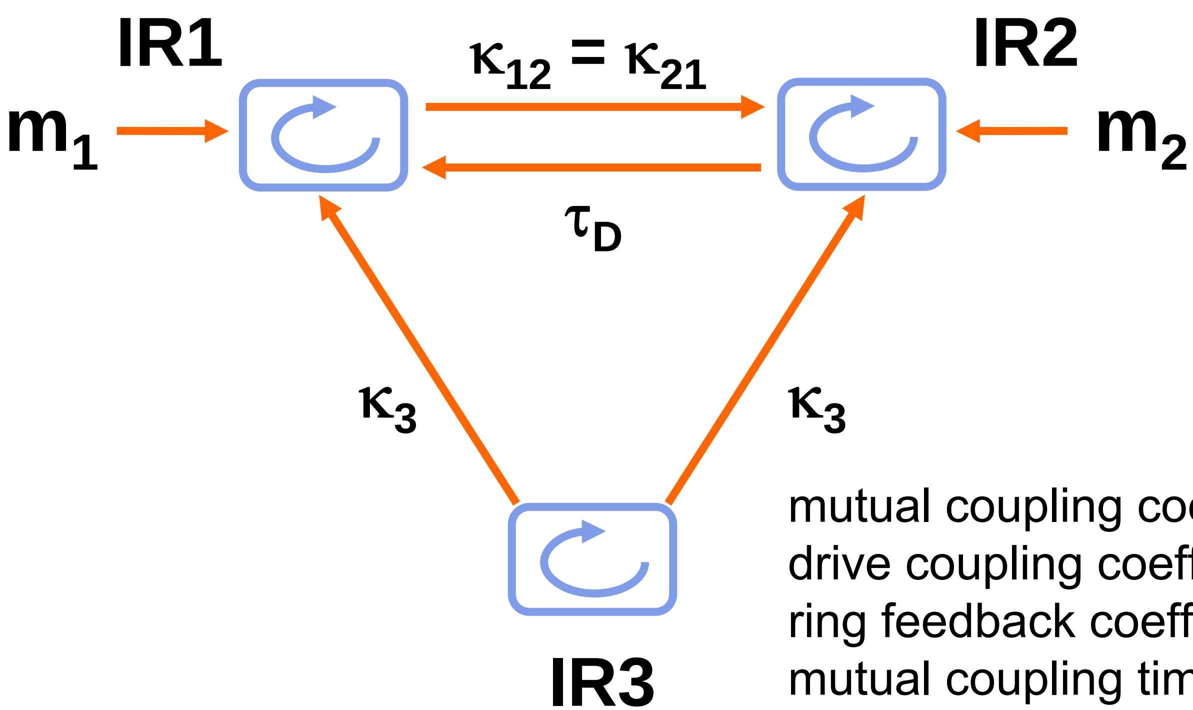
$$E(t+\tau_R) = f\,\{E_{in}(t),\ w(t)\}$$

$$dw/dt = g\,\{w(t),\ |E_{in}(t)|^2\}$$



Scheme for Isochronal Synchrony

- Symmetrically inject the signal of a drive system (IR3) into the two mutually coupled IRs.

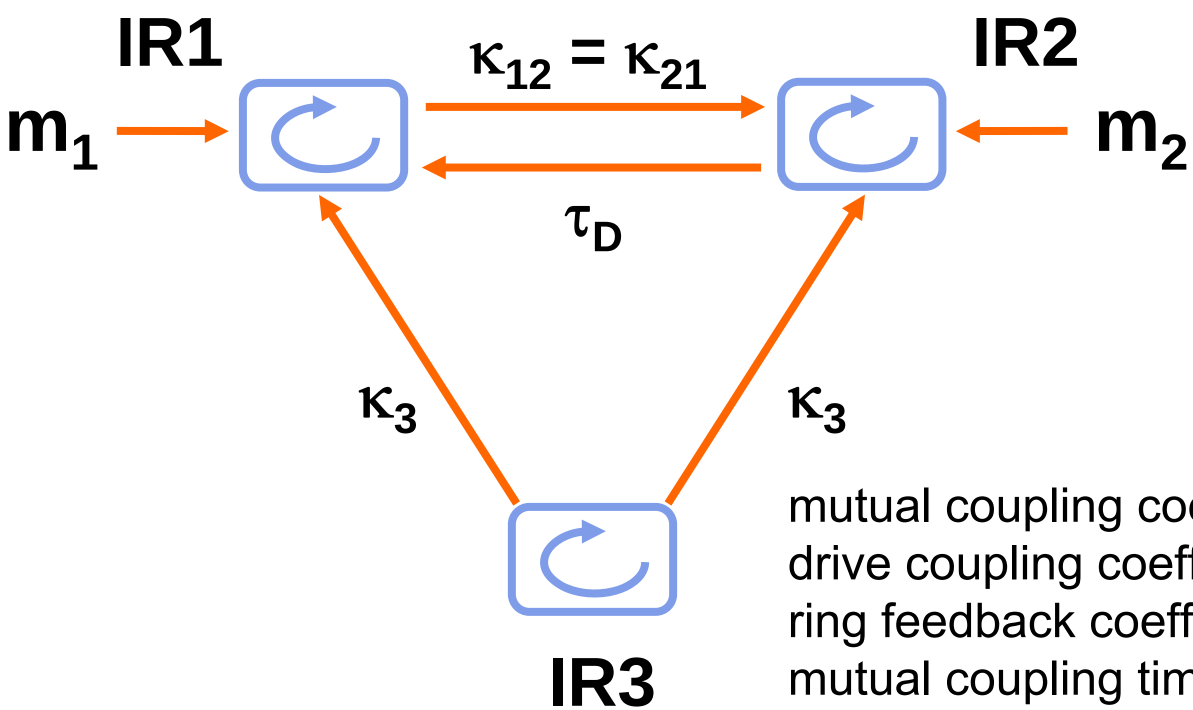


mutual coupling coeff.	=	$\kappa_{12} = \kappa_{21}$
drive coupling coeff.	=	κ_3
ring feedback coeff. (IR1 and IR2)	=	$1-\kappa_{12}-\kappa_3$
mutual coupling time delay	=	τ_D
ring roundtrip delay	=	$\tau_R = 1$

Injected Msg — Rec. Msg

Self-Feedback — Coupling — Drive

$$E_{1,in} = \boxed{(1-\kappa_{12}-\kappa_3)\, E_1(t)} + \underline{m_1(t)} + \boxed{\kappa_{12}\, E_2(t-\tau_D)} + \underline{m_2(t-\tau_D)} + \boxed{\kappa_3\, E_3(t)}$$



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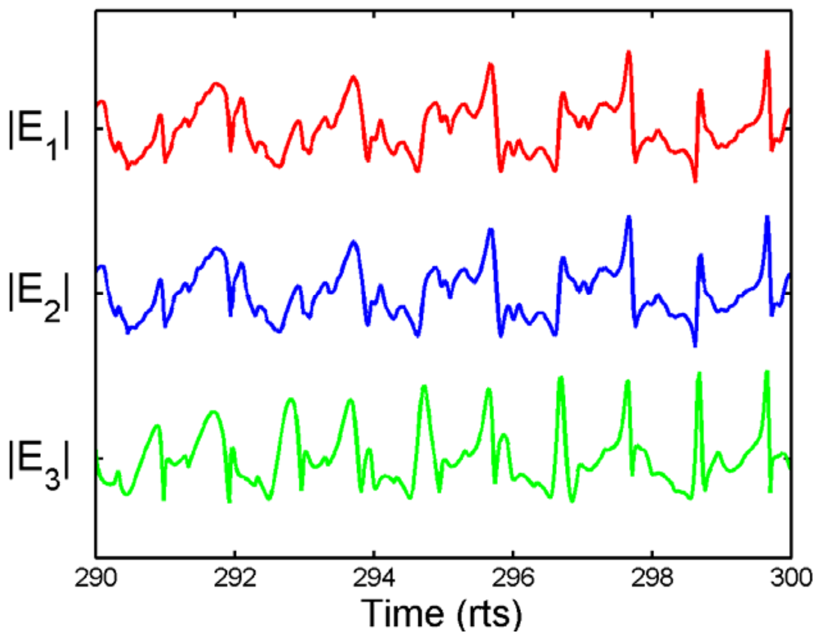
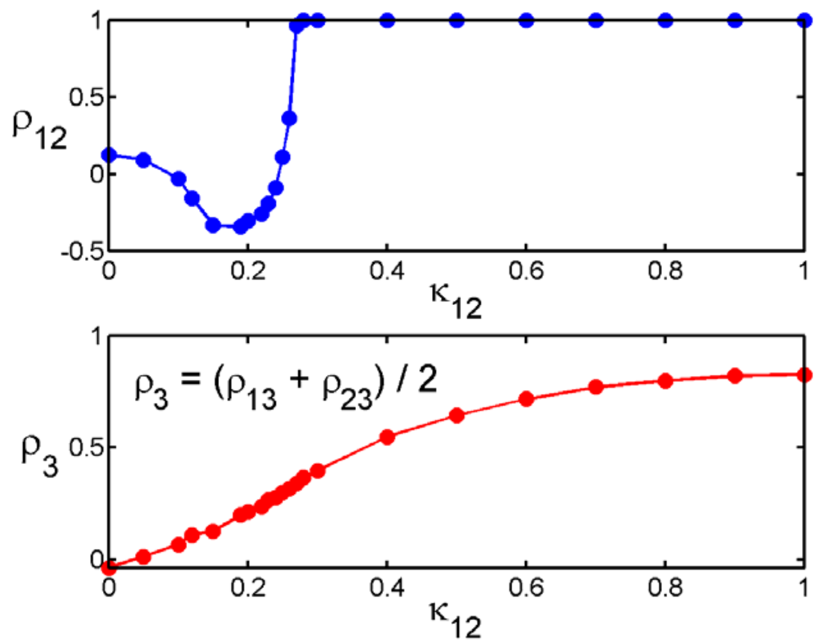
Isochronal Synchrony

- Stable above critical drive coupling.
- Generalized synchrony of IR1 and IR2 to drive IR3.

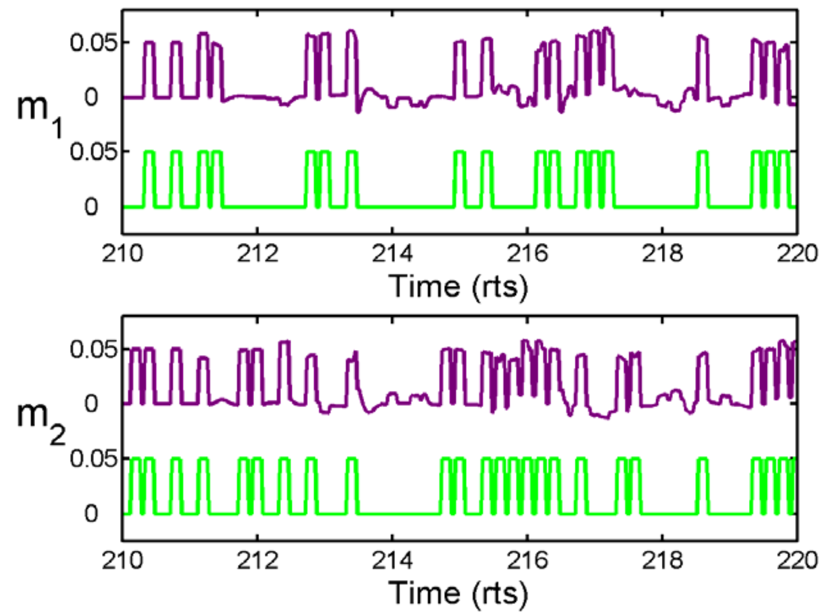


Cross-correlation = ρ_{ij}



Bidirectional Messaging

- Two-way chaos modulation technique:
  - $E_1(t) \rightarrow E_2(t)$
  - IR1 receives $E_2(t) + m_2(t)$.
  - Hence, $[\cancel{E_2}(t) + m_2(t)] - \cancel{E_1}(t) \rightarrow m_2(t)$.
- Difference in transmitted messages perturbs perfect synchrony. BER < 10^{-4}.



Purple – Decoded
Green – Transmitted

Extensions

- Isochronal synchrony holds for:
  - Non-identical drive signals (Rössler oscillator).
  - Three coupled IRs in a chain each driven by a fourth IR.
- Similar systems of nonlinear oscillators.